Before the

FEDERAL COMMUNCATIONS COMMISSION

Washington, D.C. 20554

In the Matter of	)	
	)	
Application of Space Exploration Holdings, LLC, For Modification of Authorization for the SpaceX NGSO Satellite System	)))	File No. SAT-MOD-20200417-00037

To: The International Bureau　　　　Aug. 7, 2020

<u>REPLY COMMENTS OF KEPLER COMMUNICATIONS INC.</u>

Kepler Communications Inc. ("Kepler") submits these comments in reply to the consolidated opposition ("Opposition") of Space Exploration Holdings, LLC ("SpaceX") to various commenters and petitioners of its recent request to modify its authorization ("Modification") which, *inter alia*, seeks to relocate 2,824 satellites to the 540 – 570 km altitude range.[1] The Commission has previously recognized that any modification that would create significant interference would necessarily act to harm the public interest, and that applications for modification must demonstrate that they will not raise such interference.[2] In its previous comments, Kepler provided a dynamic, time-varying analysis demonstrating that the modified SpaceX system would substantially increase interference to Kepler's services. Instead of addressing these concerns, SpaceX has contended that these demonstrations are made moot by

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[1] *See Consolidated Opposition to Petitions and Response to Comments of Space Exploration Holdings, LLC*, IBFS File No. SAT-MOD-20180319-00022 (Jul. 27, 2020) ("*Opposition*"); *Application for Modification of Authorization for the SpaceX NGSO Satellite System*, IBFS File No. SAT-MOD-20180319-00022 (Apr. 17, 2020) ("*Modification*").

[2] *See* Petition to Deny of Kepler Communications Inc., IBFS File No. SAT-MOD-20200417-00037, at note 3 ("*Kepler Petition*").

asserting that Kepler and SpaceX systems already trigger the default coordination threshold 100% of the time, thereby making any new increases in interference irrelevant. In an attempt to prove its point, SpaceX leverages a variety of flawed assumptions to exaggerate the current extent of interference between the Kepler and SpaceX systems within a set of narrow circumstances. They then conclude, incorrectly, that their exaggerated showings can be logically extended to all other possible interference scenarios. SpaceX's analysis does not stand up to scrutiny and ultimately fails to address or resolve Kepler's interference concerns. Further, SpaceX seeks to minimize the outsized impacts of its unprecedented constellation on the orbital debris environment, and its responsibility to properly mitigate it. After two other previous modifications, SpaceX's newly proposed system scarcely resembles that which it filed in 2016. In light of the comprehensive opposition from numerous commenters, the Modification is revealed to introduce a plethora of problems to the physical and frequency interference environments and must be conditioned appropriately to address them, or else rejected.

SUMMARY

Building on the findings of Kepler's Petition, presented herein is a detailed analysis of the impact of the Modification on the interference environment, as it affects Kepler's authorized system. SpaceX has posited that Kepler's earlier interference demonstrations, which it did not refute, were instead made moot based on two flawed assertions: that Kepler's uplink operations already exceed the -12.2 dB I/N coordination trigger 100% of the time, and that a band-splitting event in one direction will necessarily trigger a simultaneous band-splitting event in all other directions. SpaceX claimed that because the band will always be split, that any further increase in interference shown thereafter is irrelevant. Ultimately, neither assertion stands up to scrutiny. The analysis presented by SpaceX was in fact heavily misleading; it abandoned any idea of a good faith representation of Kepler's system and instead chose to leverage unrealistic parameters to skew its results. Moreover, in-line events in one direction (e.g. uplink) will not necessarily imply the presence of an in-line event in another direction (downlink). Without these two assumptions, SpaceX's refutation crumbles. Notably, SpaceX did not deny Kepler's demonstrations of increased interference, but sought only to nullify their significance. Given SpaceX's failure to do so, Kepler turns its attention to the precise extent of the interference generated by the Modification. As it stands, the proposal threatens to produce relative increases in interference of over 2000%, depending on the direction of interference and the latitude of a given victim earth station.[3] Within the continental US, the Modification would cause in-line occurrences to increase from ~ 5 – 24 % of the time to ~ 70 – 77%. In some circumstances, the Modification introduces interference where previously *none had existed at all*.[4] Additionally, questions remain regarding which ITU filing(s) will govern the proposed Modification, and whether other operators will be able to adequately assess its compliance with ITU EPFD limits.

On the subject of orbital debris, if physical coordination were really as trivial as SpaceX seems to suggest, one would expect many inter-operator agreements to have materialized over the preceding four years.[5] Yet Kepler, in its interactions with the space community, is unaware of any such agreements. Kepler's own agreement with SpaceX remains incomplete - complicated by the seemingly ever-changing parameters of the constellation. Now, SpaceX's newly proposed orbits propose to move over 500 satellites into sun-synchronous orbits, directly on top of Kepler's already authorized system. Any future maneuvers executed by Kepler to avoid these satellites would

[3] Earth station latitudes of 35°N, 80°N, 85°N, and 90°N were assessed.
[4] See Appendix, Table 5 - Table 7. Under the current authorization, the majority of Kepler operations at 90°N were virtually interference-free. Among other things, SpaceX's newly proposed orbital configurations introduce substantial new levels of interference.
[5] *See* Opposition at note 15 ("SpaceX will have little difficulty physically coordinating its system with other NGSO operators").

require an interruption of service, and can therefore be treated as a form of frequency interference. To maintain interference at current levels, SpaceX must therefore be made to assume responsibility for any conjunction avoidance maneuvers that materialize as a result of the proposed modification. Finally, SpaceX's avoidance system largely remains a black box to other operators, a pillar of uncertainty underpinning all third-party analyses. These uncertainties carry important weight when assessing the relative risk posed by any one of SpaceX's 4,408, 260 kg satellites in its proposed 30 km shell. SpaceX's reliance on the outdated 'zero-risk assumption' - that satellites equipped with propulsion are considered to have zero collision risk - has now facilitated a proposal which, if any reasonable risk is actually assumed, would quantifiably disrupt the stability of Low Earth Orbit. Though a reduction in altitude may confer some benefits on orbital lifetime, SpaceX does not provide proper justification for its proposed changes to its planar configurations. Instead, its new planes now cover a wider area than before, extending the area over which SpaceX can claim harmful interference and potentially exert de facto regulatory control over other operators.

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I. THE OPPOSITION FAILS TO EXPLAIN THE MODIFICATION'S INCREASED INTERFERENCE

SpaceX Does Not Deny that the Modification Will Cause Increased Interference

SpaceX apparently does not contest the increased magnitude of interference shown by Kepler's earlier analysis. Instead, they rely on two flawed claims in an attempt to invalidate it. One, that a band-split trigger in any one of the four possible interference domains (To/From SpaceX Uplink and To/From SpaceX Downlink) will necessarily result in a band-split within the other three, and that Kepler's system triggers a band-split 100% of the time in the Uplink To SpaceX domain. We will demonstrate later why both of these claims are flawed, but it is worth noting that this evasion is effectively a tacit admission that the Modification will indeed cause increased interference into some systems, including Kepler's.

The Opposition Used Grossly Misleading Assumptions

First, SpaceX provides an analysis that appears to show Kepler operations exceeding the default coordination trigger of -12.2 dB 100% of the time. Rather deceptively, it presented its results under the guise of using conservative values generally, despite instead using exaggerated parameters.[6] For context, the source of the parameters is a pending earth station application for a small group of hybrid LEO-GEO terminals that contains a range of transmission characteristics necessary to

[6] *See* Opposition. SpaceX framed its analysis as being generally conservative. For example, when it stated that it used "publicly available system parameters and, when relevant parameters were not available, conservative assumptions" (page A-1); when it noted its use of an ITU-R standard antenna pattern "[t]o ensure a conservative result, [...] which would tend to minimize the interference to SpaceX's uplinks" (page A-3); and when it claimed that "[its] analysis assumes uplink transmissions from the smallest user terminal described in Kepler's filings [...] [u]plink interference would be even more severe from larger Kepler earth station antennas." (page A-6). What SpaceX does not disclose is that when it did use publicly available parameters, it would select ones in an effort to exaggerate the perceived interference.

execute various service and control functions to both NGSO and GSO spacecraft. For example, the application sets a minimum bandwidth of 1 MHz for transmissions from the terminals to account for typical channel sizes used by GSO spacecraft, such as those on the Permitted Space Station List (an alternate point of communication listed on the filing).[7] Transmissions to and from NGSO spacecraft across 1 MHz might be used in rare situations for tracking or debugging purposes.[8] After internally replicating SpaceX's results, it is clear that SpaceX erroneously applied this minimum bandwidth to Kepler's NGSO user terminals broadly, while also assuming terminals would transmit at their theoretical maximum power. This acted to inflate the perceived power density - and therefore interference - to wildly unrealistic levels. In general, Kepler's user terminals will spread their power over much larger bandwidths and with moderate power back-off.[9] A more realistic assessment of Kepler's uplink operations are given below:

Table 1: Example representative Kepler user terminal parameters

Terminal type	Configuration	Power	Bandwidth	EIRP Spectral Density (dBW/Hz)
0.65 m	Nominal Min	6W	10 MHz	-25.22
0.65 m	Nominal Max	6W	20 MHz	-28.23
2.4 m	Nominal	40W	125 MHz	-17.25

Kepler notes that in the rare circumstances that it would use the 1 MHz bandwidth, such as to accommodate a narrow GSO channel spacing, it is already required to comply with input power

[7] *See* FCC IB, *Approved Space Station List*, URL: https://www.fcc.gov/approved-space-station-list (acc. Aug. 4, 2020).
[8] Kepler has made it clear in coordination conversations with SpaceX that this configuration is unlikely to be used with its NGSO system.
[9] Generally, a buffer is left in the power budget in the event that user terminals need to increase power to overcome transient losses, such as rain fade.

density limitations under §25.212(c)(2). Kepler stated in its earth station application that its typical transmission to GSO from a 65 cm user terminal would use 6W input power at 1.5 MHz.[10] Such operations would result in an EIRP density of -17 dBW/Hz, which in itself is more than 3 dB lower than the -13.27 dBW/Hz value used by SpaceX in its assessment.[11] Importantly, Kepler's operations are in accordance with the rules of both the Commission and the ITU for GSO earth stations, and are protected under those rules.[12] SpaceX also asserts Kepler's larger antennas "would be even more severe", but doesn't reveal in what ways it might have embellished those figures as well.[13] Conversely, SpaceX itself cited the use of larger earth stations as a means of reducing the probability of in-line interference events when it sought to modify its use of Ku-band for feeder links.[14] Rather expectedly, and as will be shown below, even interference caused by very large earth stations would not be sufficient to validate SpaceX's conclusions.

Kepler Uplink Operations Do Not Saturate the Band Splitting Trigger

SpaceX's assessment presents an unrealistic scenario to draw exaggerated conclusions about the interference environment. For example, consider the plot provided by SpaceX purporting to show Kepler's uplink operations from a ground station located at 90°N.

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[10] SpaceX claims to have used Kepler's smallest terminals in its assessment, which would correspond to a 65 cm dish diameter.

[11] *See* Opposition, at A-6 ("this analysis assumes uplink transmissions from the smallest user terminal described in Kepler's filings, with an EIRP of -13.27 dBW/Hz").

[12] *See* ITU-RR Article 22.2 ("Non-geostationary-satellite systems shall not cause unacceptable interference to and, unless otherwise specified in these Regulations, shall not claim protection from geostationary satellite networks in the fixed-satellite service and the broadcasting-satellite service operating in accordance with these Regulations.").

[13] *See* Opposition, at A-6.

[14] *See* SpaceX, *Further Consolidated Opposition to Petitions and Response to Comments of Space Exploration Holdings, LLC*, IBFS File No. SAT-MOD-20181108-00083, at 9 (Feb. 21, 2019) ("Although user and gateway uplink beams may transmit at the same EIRP, gateway earth stations use larger antennas with better sidelobe characteristics and therefore reduce the probability of an in-line interference event with another NGSO.").

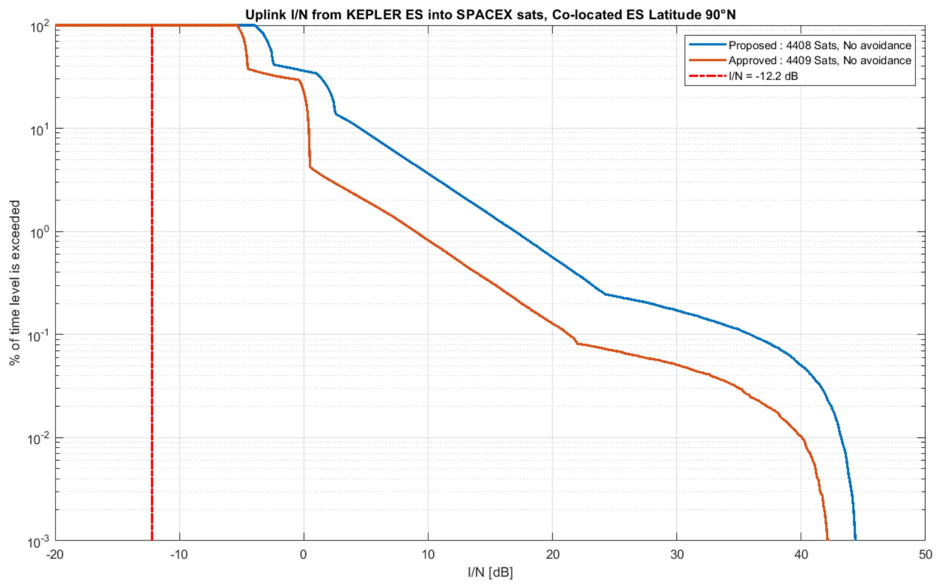

Figure 1: Incorrect SpaceX plot purporting to show Kepler's uplink interference into SpaceX satellites.

Using grossly inflated assumptions, SpaceX's plot presents Kepler's uplink as exceeding the -12.2 dB coordination trigger 100% of the time. We will show later how this effect is reduced dramatically (down to ~2%) when normal criteria are used. But first, we note separately that SpaceX's plot appears to also have a visible technical error. Generally, the shape of an I/N curve implies information about the number, magnitude, and character of in-line events. It is highly dependent on the visible orbital configuration as seen from the subject earth station. SpaceX's plot shows a nearly identical curve profile between their current authorized configuration and their proposed configuration, despite having completely different in-line geometries at the latitude in question.[15] Kepler cannot confirm whether this error is localized to the 90° plot or if it persists

[15] *See infra*, Figure 7 and Figure 8. Under the current authorization ("4409"), a station at 90°N latitude would only ever see SpaceX satellites rising up from its minimum elevation of 40° to a maximum elevation of 44.8° above the horizon. These satellites would consist of those in SpaceX's currently authorized 81° inclination planes at 1,275 km. Kepler's satellites would only be seen to rise to ~29° elevation, and would begin transmitting at 10°. Under the proposed Modification ("4408"), the addition of 10 new orbital planes at 97.6° inclination means a station at 90°N latitude would now see SpaceX satellites traverse through the same space as Kepler's, creating a zone vulnerable to direct overlaps, where previously there had been a persistent minimum separation of at least 11°. This represents a complete re-organization of in-line geometries, and the I/N profile would reflect that.

throughout the rest of SpaceX's results. Below, Kepler provides the corrected figure, using the correct geometries and nominal transmission characteristics. To allow proper comparison, Kepler simulated its smallest terminals using criteria provided directly to SpaceX in its ongoing coordination discussions (i.e. an EIRP spectral density of -26.26 dBW/Hz).

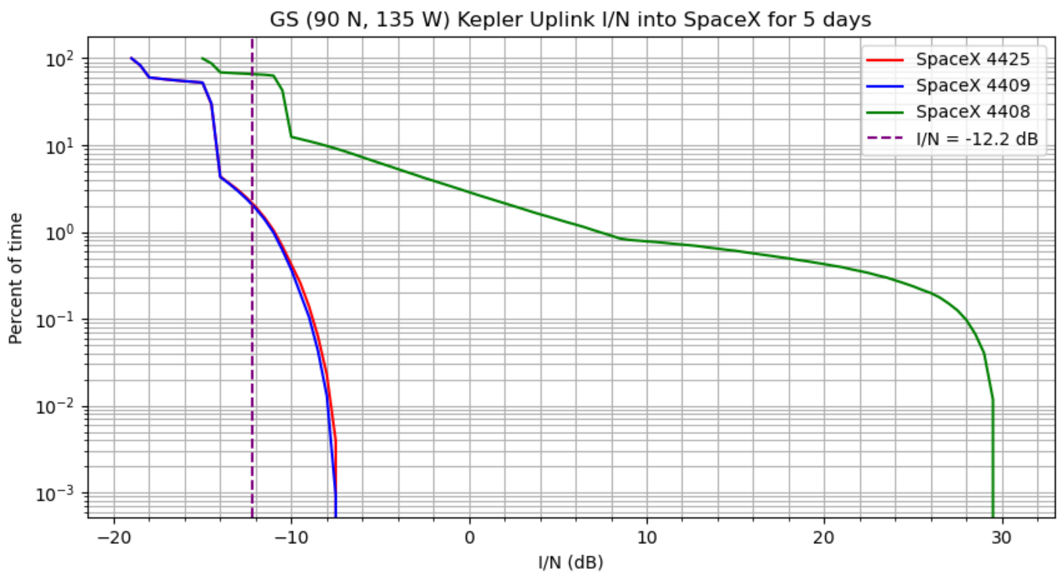

Figure 2: Corrected Kepler Uplink into SpaceX satellites from an earth station at 90°N.

As expected, SpaceX's new geometries indeed drastically change the profile of the 4408 curve relative to its predecessors. Under the current authorization (4409), Kepler's uplinks will trigger the band-splitting procedure only 2.1% of the time, not 100% as SpaceX suggests. Under the Modification (4408), the coordination procedure is triggered 46.1% of the time – a **2000% increase**. This simulation was also repeated at the other latitudes of interest.[16]

[16] Visible in the 35°N plot is an overall increase in interference between SpaceX's original filing (4425) and its current authorization (4409). Though Kepler could not supply quantitative simulations at the time the 4409 authorization was being considered, SpaceX dismissed its qualitative arguments and claimed they did not withstand scrutiny.

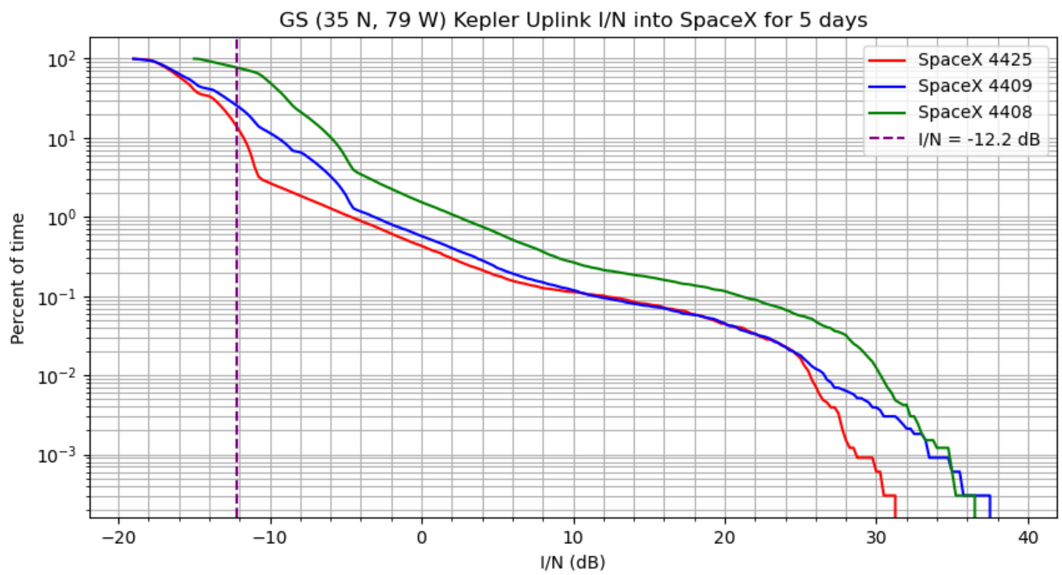

Figure 3: Kepler Uplink into SpaceX satellites from an earth station at 35°N.

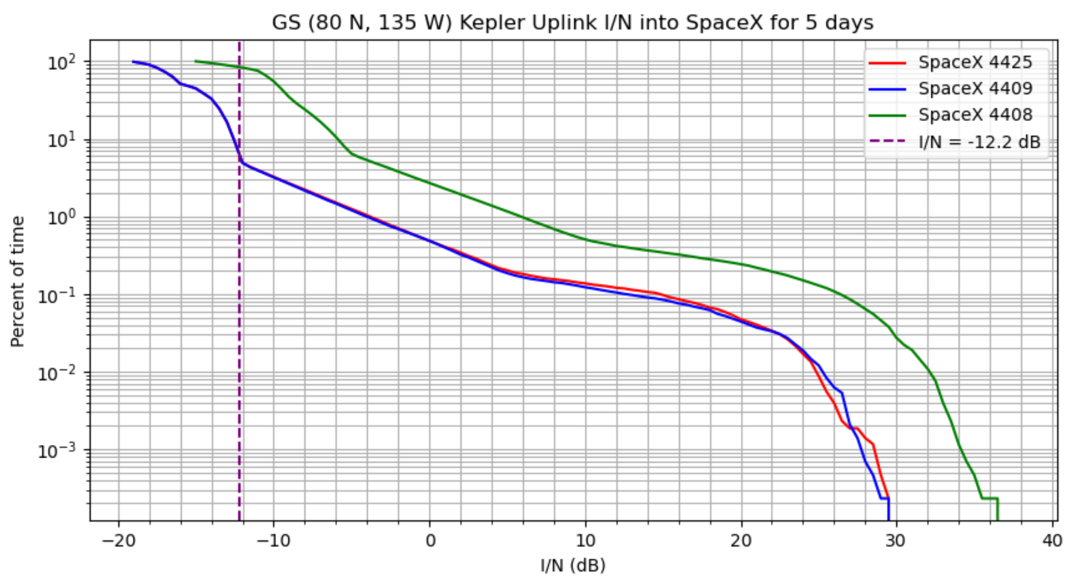

Figure 4: Kepler Uplink into SpaceX satellites from an earth station at 80°N.

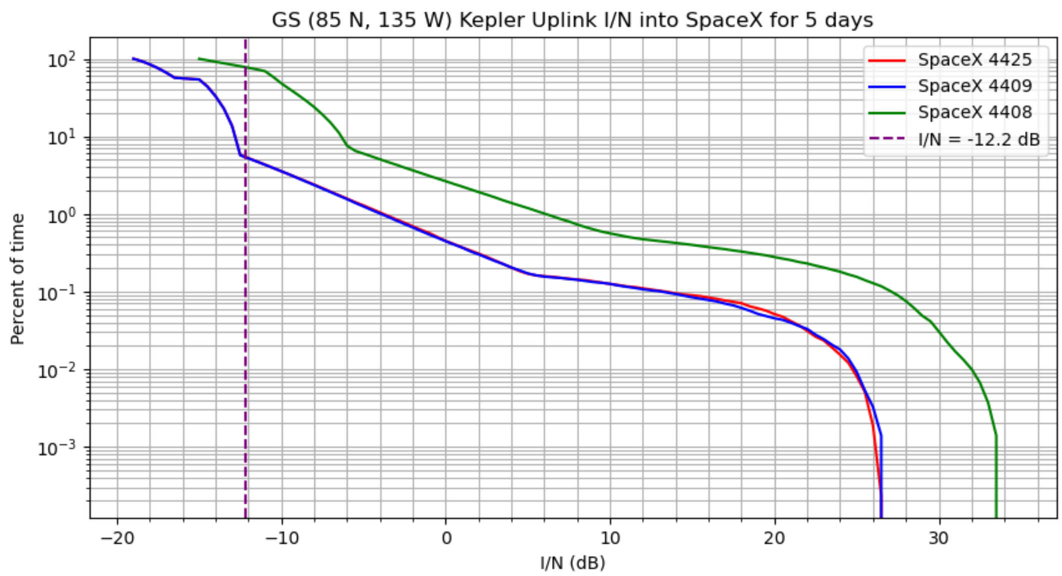

Figure 5: Kepler Uplink into SpaceX satellites from an earth station at 85°N.

In reality, Kepler's system presents a low interference risk with the currently authorized SpaceX system across all latitudes. This is shown in the table below, alongside the increases that would be caused under the Modification.

Table 2: Kepler into SpaceX Uplink. Table shows percent time the ΔT/T=6% (-12.2 dB) trigger is exceeded, as experienced at various latitudes.

Earth Station Latitude	Interference into SpaceX Uplinks (Current authorization)	Interference into SpaceX Uplinks (Modification)	Percentage Increase
35 N	24.1%	69.5%	**188%**
80 N	4.9%	76.7%	**1472%**
85 N	5.4%	65.0%	**1095%**
90 N	2.1%	46.1%	**2083%**

To further lay to rest SpaceX's ludicrous claim that Kepler's larger earth stations will somehow make the interference environment worse when SpaceX's wouldn't, Kepler provides the CDF I/N plot for a 2.4 meter earth station at a latitude of 35 degrees.

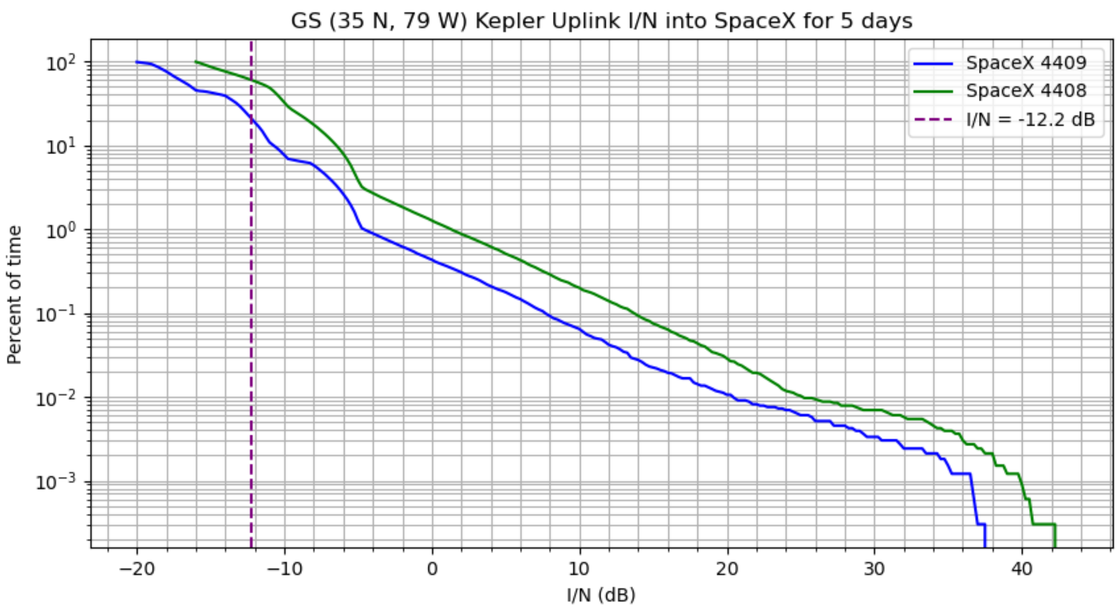

Figure 6: Kepler Uplink into SpaceX satellites from an 2.4m earth station at 35°N.

As is evident from the figure, and in keeping with SpaceX's own line of thought prior to this modification, the interference from larger earth stations do not skew the results in favor of SpaceX's misguided assertions.

Evidently, the amount of time spent in excess of the coordination threshold in all circumstances increases considerably after the Modification. Throughout the CONUS alone, interference as a result of the modification would cause in-line events to occur around ~ 70 – 77% of the time, where previously they occurred at ~ 5 – 24%. For completeness, Kepler has provided similar tables for the other three possible domains of interference in the Appendix, namely Kepler-SpaceX downlink, as well as SpaceX-to-Kepler Uplink and Downlink.

A Saturation of the Band Splitting Trigger in One Direction Does Not Impact Sharing in the Other Direction

SpaceX oddly asserts that "the modification will cause no material change to the number or duration of in-line events because [Kepler's] own uplinks will exceed the trigger long before any effect on their downlinks would do so.".[17] However, it simply does not follow that an in-line event in the uplink direction would necessarily require a simultaneous band-split in the downlink direction, as SpaceX suggests. At first glance, one might think that when two satellites come within a certain proximity, an event is triggered, regardless of the direction of transmission. However, in-line events are **not** determined by angular separation, but by the received power threshold ΔT/T. This is dependent on a number of factors, which include angular separation, but also antenna pattern, beam steering angle, power density, and even pointing scheme. In fact, because Ku-band uplink and downlink operations take place in different frequency bands, it is all but guaranteed that these assessments will look fundamentally disparate. Consequently, the characteristics used in each direction will uniquely influence what angular separation constitutes an in-line event *in that direction only*.[18] For example, a high power uplink transmission from an antenna with a large beamwidth might exceed the -12.2 dB I/N trigger at a separation angle of 40°, whereas a low power downlink from an antenna with small beamwidth may exceed the -12.2 dB trigger at a 2°

[17] *See* Opposition at 29.

[18] The exact angular separation necessary to trigger an in-line event is dependent on antenna pattern, power, beam steering, and tracking strategy. Logically these *must* differ if not for the simple fact that Ku-band uplink and downlink operations occur in different frequency bands, and are subject to different limitations. The antenna designs and transmission strategies will differ correspondingly.

separation. In-line event assessments in each direction are thus almost entirely *independent of each other*. This fact alone disproves the notion on which SpaceX's entire argument rests:

> *"These assertions fail to consider the larger question that is critical in assessing changes to the interference environment: whether the proposed modification would increase the number of in-line events during which two NGSO operators would be required to split a spectrum band under Section 25.261 in the absence of a coordination agreement. Making this determination requires more than just looking at the effect on downlinks in isolation. To the contrary, the analysis must look at all four scenarios discussed in this section to see whether a change in any one is material. Here, as demonstrated in Appendix A, existing interference from other NGSO systems into SpaceX uplinks (even at the levels experienced at its currently assigned orbital altitudes) will overwhelm any effect SpaceX's modified operations may have on their respective downlinks."*[19]

Again, even if 100% band-split saturation on the uplink domain were observed, there could easily still be room available for increased interference in the downlink domain. SpaceX's assertions that saturation in one domain would "overwhelm" those in another are simply incorrect. Regardless, Kepler's analyses clearly demonstrate that the Modification would produce significant increases in all four possible domains of interference, relative to current levels.[20]

To Reiterate, the Modification Will Cause Significantly Increased Interference to Kepler's System

Building on the analysis provided in Kepler's earlier Petition, here we provide more detail on the extent of interference caused by the Modification. As previously discussed, SpaceX has claimed that its modification "will not increase the amount of time that the parties will have to split common spectrum in the absence of a coordination agreement". Kepler has already demonstrated how not only is this inaccurate, but the increase is on the order of 2000%. For geometric reasons,

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[19] *See* Opposition, at 27-28.
[20] *See also*, Kepler Petition at 4 (plots showing the increase in the relative distribution of minimum-separation angles seen from latitudes of 35°, 75°, 80°, 85°, and 90°).

a station situated at 90°N latitude provides perhaps the clearest visual refutation of SpaceX's claim. The angles depicted in the figure below illustrate the current in-line environment at 90°N, an important commercial service region for Kepler.

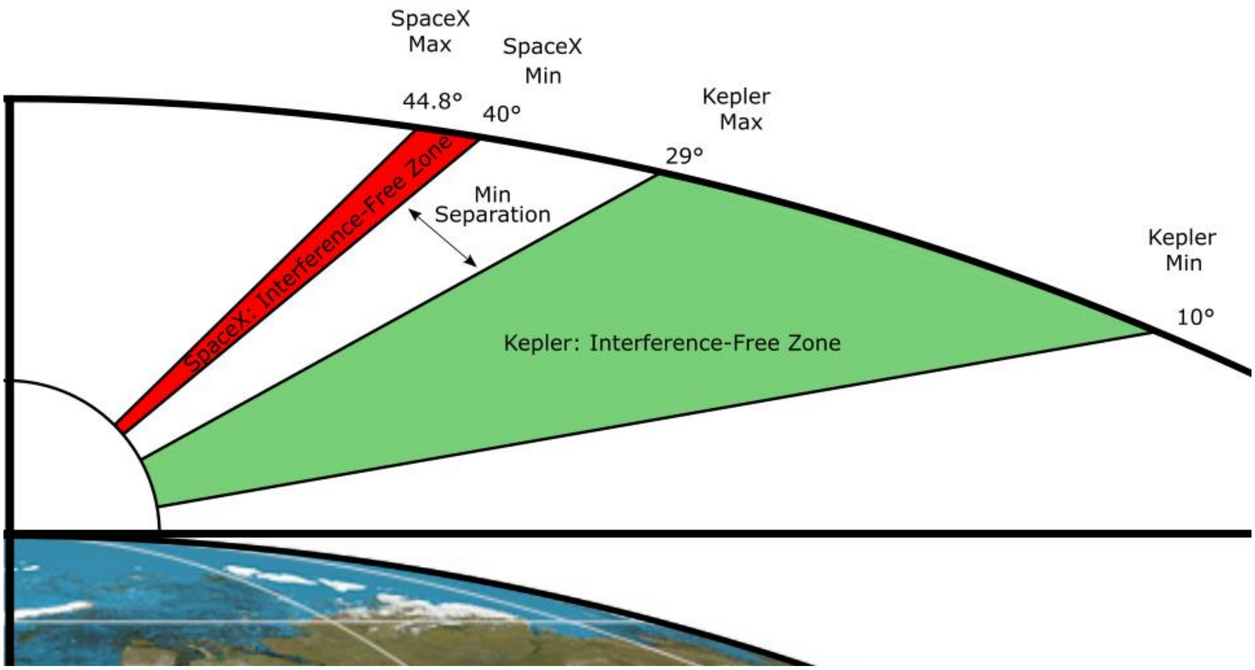


Figure 7: Current authorization, in-line environment at the poles.

The area between the lines shown signifies the zone in which SpaceX is presently authorized to provide service, bound by its minimum and maximum elevation angles respectively.[21] Notably, the Modification introduces 520 satellites into sun-synchronous orbits, and reduces the minimum elevation angle to 25°. The figure below shows how the environment would change after the Modification.

[21] A minimum elevation angle of 40° is used in SpaceX's current authorization. A maximum elevation angle of 44.8° is determined geometrically relative to SpaceX's highest inclined satellites in its current authorization.

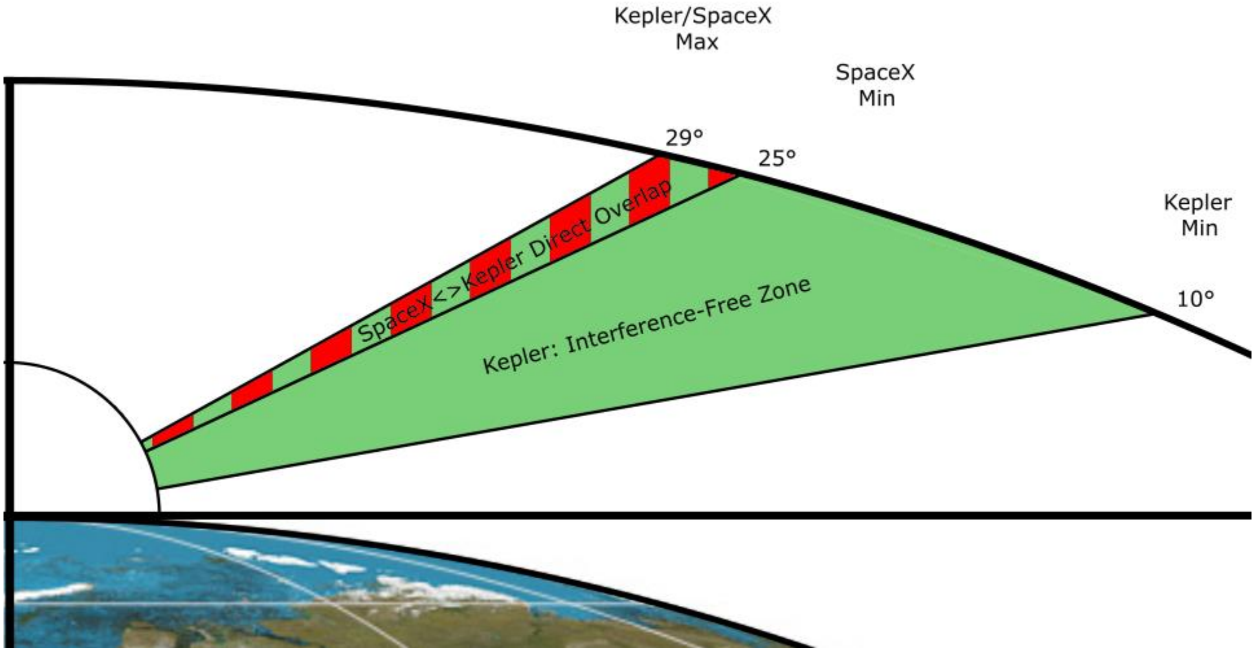


Figure 8: Modification, in-line environment at the poles. The SpaceX service zone now completely overlaps with the Kepler service zone.[22]

It is evident that in this circumstance (and to a lesser extent, in all other circumstances) that the Modification *must* increase the amount of time that the parties will have to split common spectrum in the absence of a coordination agreement. In addition, because SpaceX inserts these new satellites into nearly identical orbits as Kepler (575 km, sun-synchronous), this now opens the door to the possibility of in-line events that could *persist for very long periods of time*, as satellites in similar orbits will tend to fly together as if in formation. For SpaceX, this may not represent a significant problem since it will likely have enough satellite diversity at any particular time to route traffic away from a satellite experiencing a persistent in-line event. This is especially true at low latitudes, where Kepler may only have one or two visible satellites in the sky. For a system like Kepler's, one or more persistent in-line events would bear material impacts on its commercial service capacity. In fact, several of SpaceX's proposed orbits would overlap so closely with Kepler's that

[22] This graphic actually understates the degree of overlap. In reality, SpaceX's downlink power rolls off well below the 25° mark, as depicted in Figure 15.

in-line events would be assured *throughout the entire orbit*. To illustrate, ground tracks for Kepler's and SpaceX's proposed orbits (SSO only) are shown below.

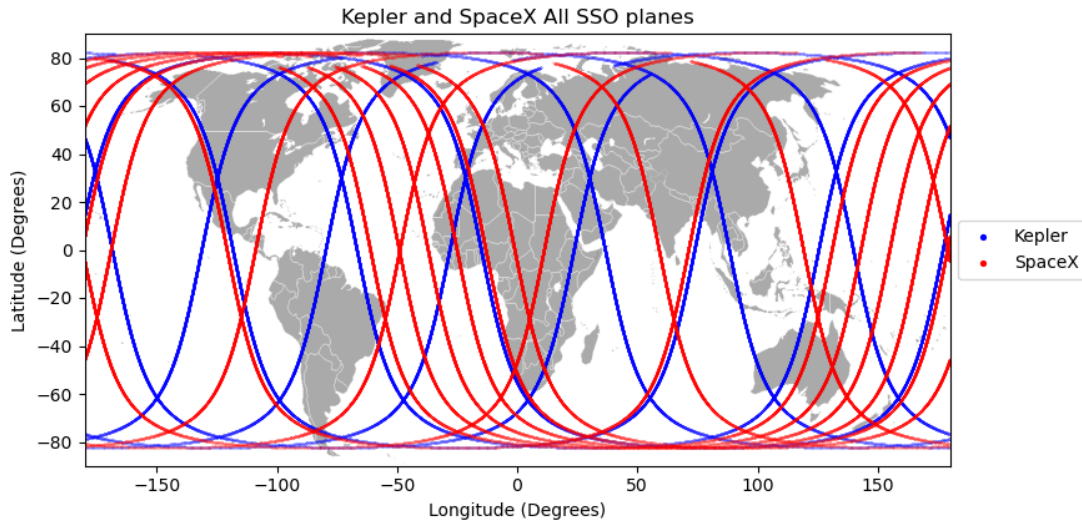


Figure 9: Ground tracks of Kepler and proposed-SpaceX sun-synchronous orbits.

Of these, it is clear that three orbit pairs are especially close together, with respective Ascending Nodes within 5° of each other. One such pair is isolated in the figure below.

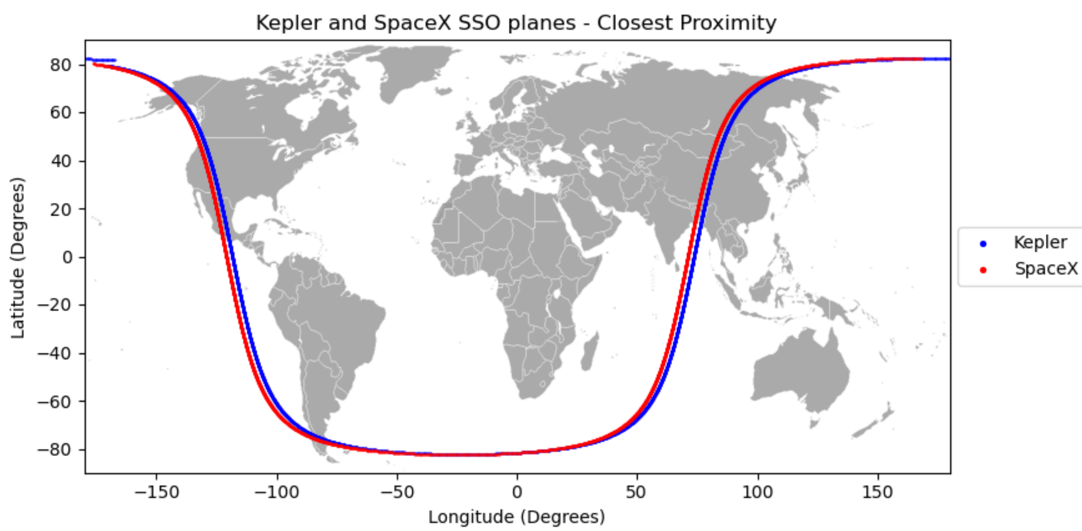


Figure 10: Ground tracks of an extremely close pair of Kepler and proposed-SpaceX sun-synchronous orbits.

Under the current authorization, there are no such overlaps between orbits. SpaceX's planar reconfiguration means that now, the real possibility exists that a significant fraction of Kepler's satellites could be constantly arrested by persistent in-line events throughout its orbit, crippling its ability to use the spectrum as envisioned when it was first authorized by the Commission. SpaceX, for its part, may get off clean, as long as it has enough satellite diversity to effectively negate those effects. One possible way it could do this is shown in the figure below.

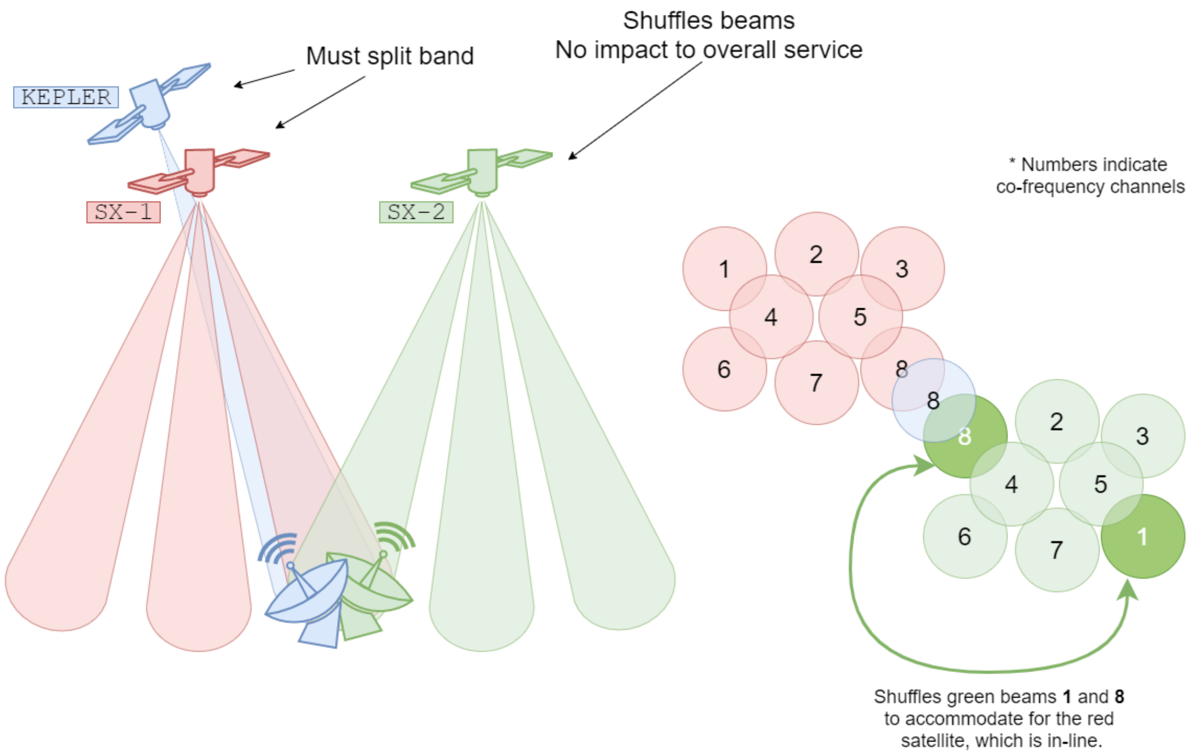


Figure 11: SpaceX's multibeam array and satellite diversity could together effectively nullify the consequences of a co-frequency band split by 'shuffling' its beam footprints. When the Kepler and red SpaceX satellites are in-line, Kepler must suffer the band split, while SpaceX can continue to serve the ground location using the full band from the green satellite. Only Kepler would experience a degradation of service.

In its earlier Petition, Kepler simulated the effect of the Modification on in-line behavior by assessing the relative distribution of minimum separation angles seen from a given victim ground station across a period of 5 days.[23]

[23] *See supra*, note 20. SpaceX appears to have incorrectly assumed that these plots show the cumulative distribution of all satellites in view at any given time. This may have helped lead them to the false conclusion that Kepler's satellites were in-line 100% of the time.

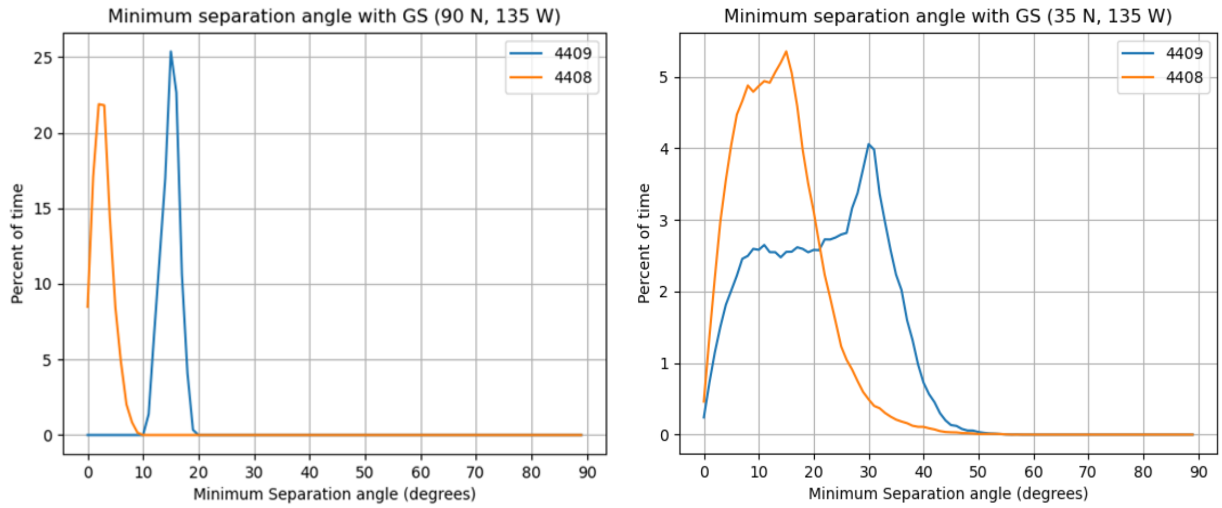
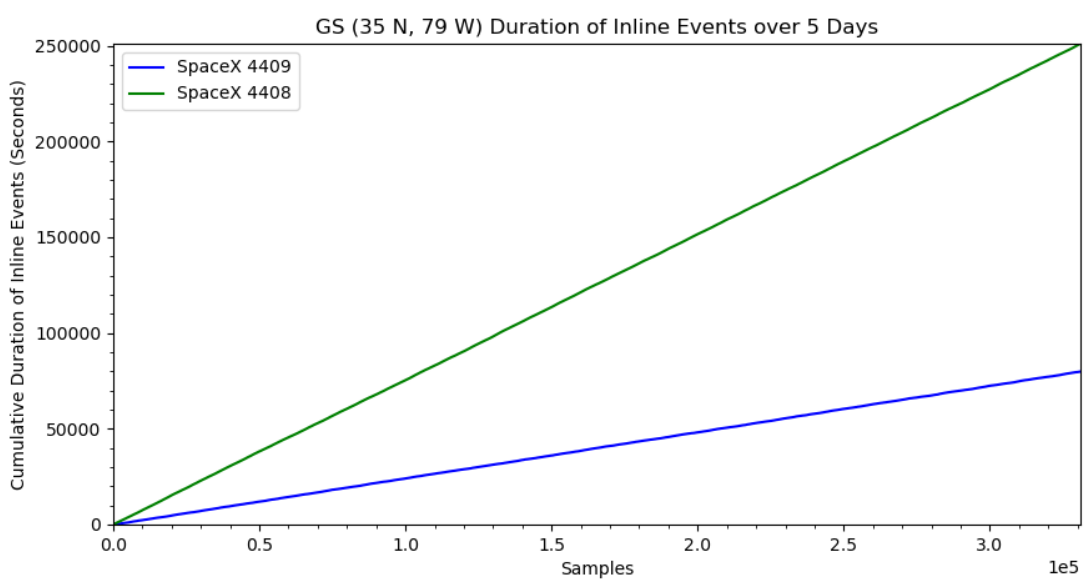


Figure 12: Minimum separation angle between the set of visible SpaceX and Kepler satellites over a victim ground station. Results show the average, dynamic proximity of SpaceX and Kepler satellites from ground stations located at 35° and 90° latitude. In all circumstances, the Modification (4408) spends more time near Kepler's satellites than the current SpaceX authorization (4409). The Modification therefore brings SpaceX satellites in closer proximity to Kepler satellites overall, increasing total in-line time.

Building on this, to alleviate any possible doubt about the impact on the number of times Kepler's constellation will be required to reduce spectrum during in-line events, Kepler has calculated the cumulative duration of all combined in-line events (i.e. those that exceed an I/N of -12.2 dB) over the same period.



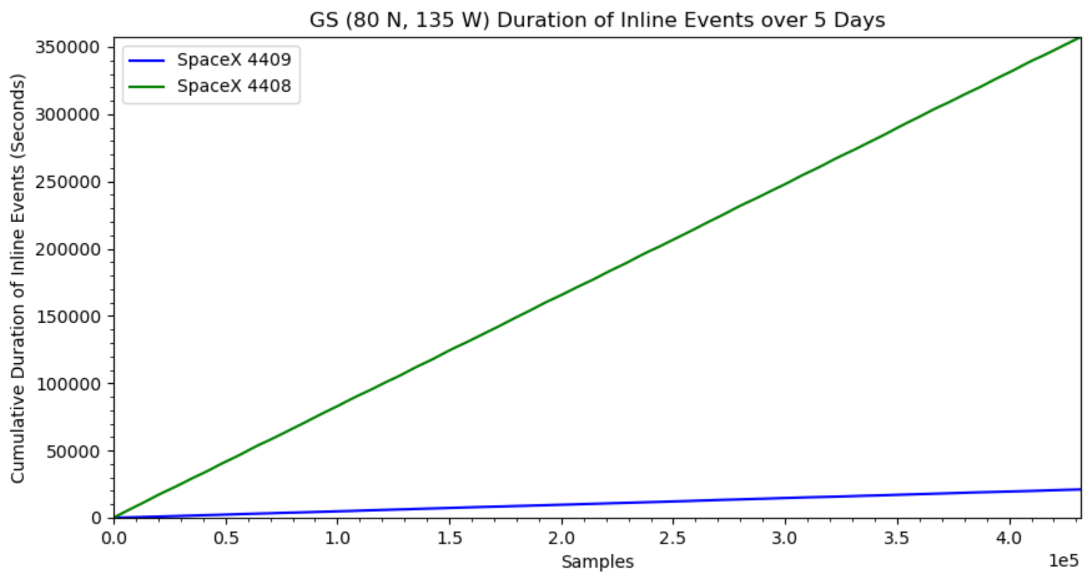


Figure 13:Cumulative duration of in-line events experienced by a single ground station over 5 days at latitudes of 35°N (top) and 80°N (bottom).

Simulations were repeated at all other latitudes of interest (see Appendix). These plots clarify the new characteristic of in-line events under the Modification, and definitively show how SpaceX's claims that both systems would be in-line 100% of the time are false. For this to be true, the lines in the figure above would need to overlap.

We also wish to correct a criticism made by SpaceX towards Kepler's earlier-filed analysis, based on a use of SpaceX's dynamically increasing EIRP, modulated as a function of satellite steering angle.[24] To be clear, Kepler *has* to incorporate these effects to properly model the system. In the Opposition, SpaceX appears to misinterpret Kepler's use of this effect as having to do with the EIRP reduction it will make as a consequence of its lowered altitude. This was not the case. Kepler

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[24] *See* Modification at 6 (Kepler's analysis accounted for the fact that "as the [SpaceX] transmitting beam is steered, the power is adjusted to maintain a constant maximum power flux-density ("PFD") at the surface of the Earth, compensating for variations in antenna gain and path loss associated with the steering angle". *See,* Opposition at note 77 (SpaceX chides Kepler for including this "'increase in EIRP' as a factor that explains the outcome of [its] analysis.", stating that "[t]o the contrary, SpaceX proposes to decrease the EIRP of its earth stations communicating with satellites operated at lower altitude.". Kepler never challenged, nor misunderstood, SpaceX's intention to reduce its relative power at its proposed altitude. This misunderstanding is particularly strange, as Kepler used SpaceX's own beam steering plot in its Petition when it described its addressing of this phenomenon.)

was referring to the dynamic EIRP profile that SpaceX uses to maintain constant PFD on the ground. Namely, SpaceX satellites increase their EIRP as they descend into lower elevation angles (and consequently higher satellite beam steering angles). This effect results in a gradual, nearly 6 dB increase in EIRP needed to maintain the same link at its new 25° elevation angles, relative to nadir. Consequently, spacecraft are now *increasing the overall power output throughout a pass*.

It is worse still. These highly glancing angles increase the roll-off of SpaceX's downlink power as its satellites descend below 25°, resulting in an appreciable spreading of the power over its "minimum" boundary. This also increases the effective size of the service region overlap in the sky.

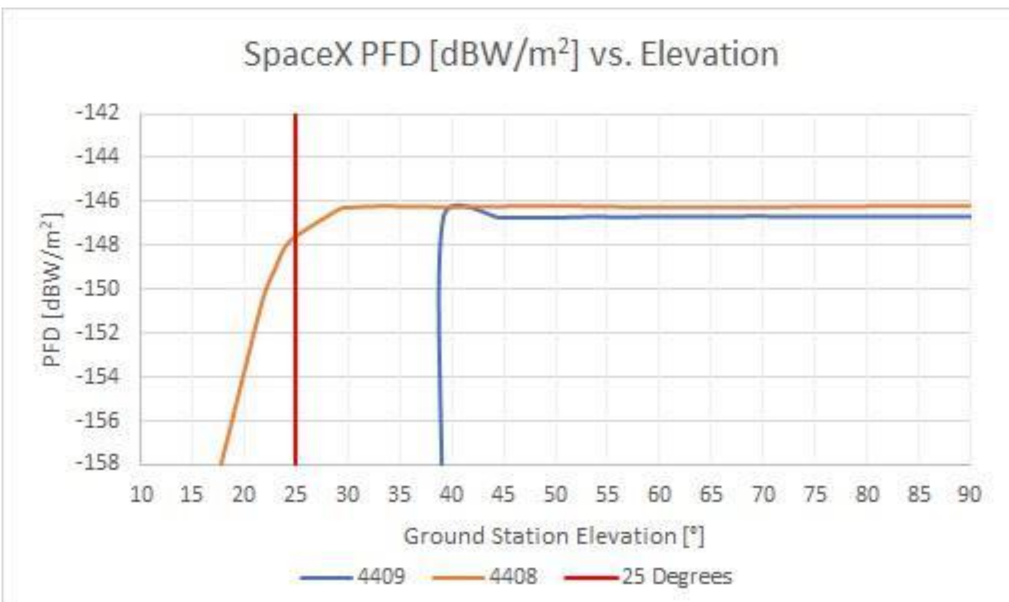

Figure 14: SpaceX downlink PFD as a function of ground station elevation. When SpaceX transmits at higher beam steering angles towards the minimum elevation boundary, its beam pattern becomes more elliptical, and it must transmit with higher EIRP to maintain containt PFD on the ground. The increased spreading at the now 25° boundary results in a much broader roll-off, increasing spurious emissions beyond the boundary and increasing interference.

This increased roll-off at the minimum elevation boundary will apply equally at all latitudes. Moreover, it is evident from the figures that the total power radiated over a given pass (represented by the area under the curves) increases under the Modification. For systems using a minimum elevation of 40° (such as OneWeb, with which SpaceX compared itself in the Modification), these power increases might not be perceptible. But for systems that use minimum elevations *below* 40°, the new power will be readily apparent. In Kepler's case, its minimum elevation of 10° means it takes the full brunt of the new power, complete with the overflow across the 25° elevation boundary.

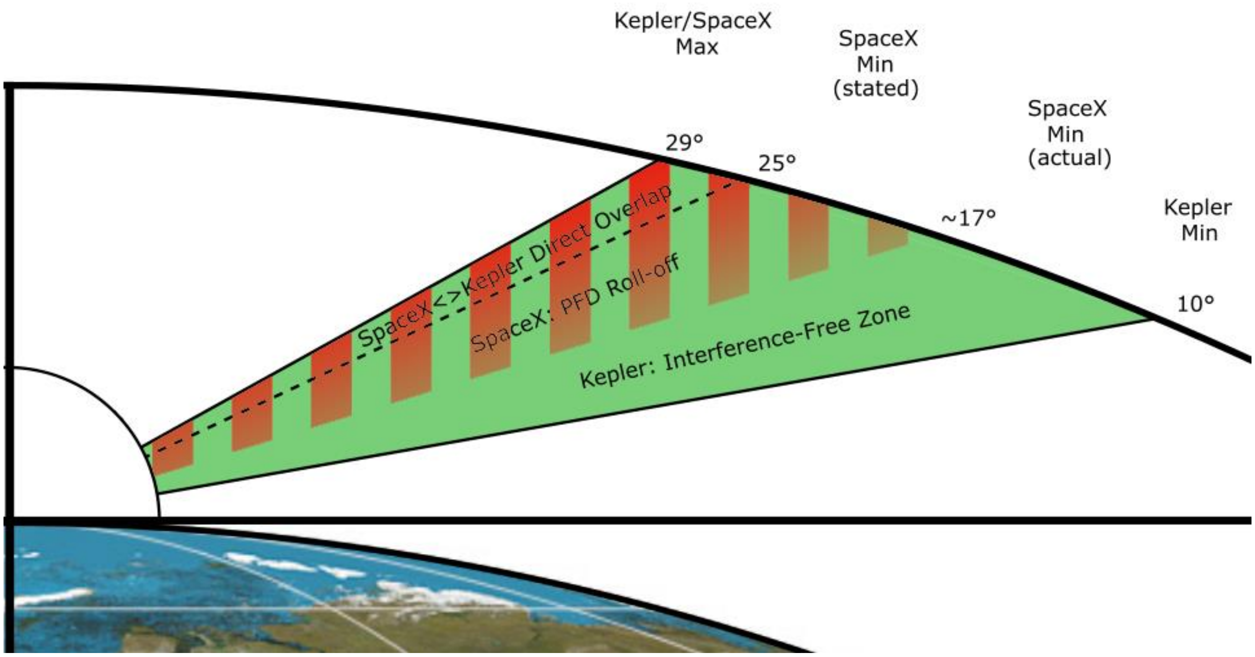

Figure 15: The in-line interference environment after the Modification, adjusted to include SpaceX's spurious roll-off emissions.

It is clear that the Modification will introduce a significant amount of new interference to Kepler's constellation. In fact, just to maintain the interference environment at its current levels, either SpaceX would have to greatly reduce its power, or Kepler would be forced to bolster its satellite diversity and expand its constellation's size. This would raise new orbital debris concerns, and degrade the interference environment for everyone else sharing Kepler's bands. The Commission should consider such knock-on effects in its assessment of whether the Modification meets the public interest. Though the consequences of the Modification on the interference environment are now apparent, it would also open the door to allow SpaceX to exert priority control over a larger dimensional footprint than it had when it filed in the 2016 processing round. In effect, the Modification arguably no longer resembles the system that was filed in 2016, and should be considered in a later processing round.[25]

It is Unclear Whether SpaceX's EFPD Will Remain Within the Limits

In its Opposition, SpaceX responded to several commenters' claims that it may not meet the EPFD requirements imposed by the Commission/ITU.[26] In its Petition, Kepler specifically requested that SpaceX identify which ITU filings would be associated with the Modification, but this request was apparently ignored. While Kepler has not performed any assessment of SpaceX's EPFD analysis, it would like to do so given the tremendous overlap between satellites and orbits that SpaceX has in its application. As it is unclear which ITU filing(s) are associated with the Modification, and masks have not been made available, the Commission should require SpaceX to disclose and publish them such that other operators have the ability to assess and comment on them prior to any grant.

Importantly, Kepler notes that while different frequencies used by a single system can, in theory, be spread across different ITU filings, any continuous frequency bands subject to common EPFD limits should only ever be contained in a single filing. Doing otherwise would raise serious complications for an EPFD assessment. To clarify, if SpaceX has one ITU filing for Ka and one ITU filing for Ku, this would not present a problem, as they can be assessed independently. We

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[25] SpaceX has previously suggested that modifications that cause interference would be appropriately considered in new processing rounds. *See* Comments of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20180319-00022, at ii (Jul. 30, 2018) ("to best serve the public interest, the Commission should heed its existing position that license modifications that add potential interference are to be considered in new NGSO processing rounds. This approach was designed to provide certainty to all NGSO applicants in a given processing round by ensuring these modifications are governed by established principles and common parameters, rather than a cascade of change upon change.").

[26] *See* Opposition, at 20-21.

request therefore that SpaceX disclose the single ITU filing associated with its Ku modification, the single ITU filing associated with its Ka modification, and the appropriate masks for each. The Commission has previously granted SpaceX's filings on the premise they obtain a favorable finding at the ITU.[27] In absence of the information requested herein, it is unclear whether SpaceX is actually meeting this requirement or whether it is effectively gaming the regulations by spreading orbits over multiple filings to reduce the measured EPFD levels. For the reasons above, conditioning the grant on a favorable finding at the ITU as the Commission has done in the past, does not alleviate Kepler's concern.[28]

II. THE MODIFICATION WILL INTRODUCE MATERIAL RISK TO THE ORBITAL ENVIRONMENT

SpaceX's Impact on Space Traffic and the Debris Environment is Shrouded in Uncertainty

Throughout SpaceX's many modifications, it has repeatedly leaned on the notion that its propulsive capabilities will guarantee it a null collision risk, effectively freeing it from an upper limit that affects other operators on the number of spacecraft it can orbit. To SpaceX's credit, its pioneering work on reusable rocketry allows it to cut the costs of launching its network to unprecedentedly low levels. But this acts to lift yet another upper limit that most other operators must contend with, the steep economics of space access. Though in many ways this might be viewed as a good thing, historically, these factors have acted as natural incentives to temper the oversupply of objects into orbit. Without them, SpaceX is in a uniquely powerful position to

[27] *See* SpaceX, *Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System*, Memorandum Opinion, Order and Authorization, FCC 18-38, IBFS File No. SAT-LOA-20161115-00118, at 5 (Mar. 29, 2018).
[28] *See* SpaceX, *Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, Order and Authorization, DA 19-1294, IBFS File No. SAT-MOD-20190830-00087, at paras. 10 and 19 (Nov. 12. 2019).

populate space in a way that other operators could never do. Careful attention should thus be paid to this peculiar situation. Though SpaceX will surely put as much effort as humanly possible into assuring the safety of their spacecraft, two facts remain: that they propose to place 8 times the amount of mass into the 540 - 570 km orbit than presently exists, and that the null-risk approximation does not reflect the real world - breaking down when the size of a system becomes sufficiently large. Moreover, even SpaceX's advanced, autonomous avoidance capabilities are ultimately nothing in the face of threats posed by small debris, accidental explosions, and limitations in Space Situational Awareness. Due to the size of the SpaceX satellites and the newly elevated local congestion, a casual observation of history shows that a *single breakup event* could easily generate a step function increase in the debris risk environment for all parties at and below that orbit. A fine-toothed scrutiny must thus be applied. Kepler discussed in its Petition a need for SpaceX to provide a comprehensive collision risk assessment for its system to clarify uncertainties around these risks.

The majority of commenters appear to share Kepler's concerns. One notable example is the fact that SpaceX's conjunction avoidance is a black box to all other operators.[29] Effectively, SpaceX is handing the steering wheel of its 1,100,000 kg fleet to a novel, unpredictable, and unverified piece of equipment. As much as Kepler commends SpaceX for its advancements, in reality things go wrong, rockets do blow up, and autonomous self-driving vehicles do crash. In its Opposition, SpaceX itself has highlighted the importance of such predictability on conjunction avoidance.[30] Unfortunately, by withholding the necessary insight into the behavior of this now-critical system, SpaceX fails to address important questions raised by other operators, such as how

[29] *See* Letter from Astroscale, IBFS File No. SAT-MOD-20200417-00037, at 4 (Jun. 30, 2020) ("*Astroscale Comments*")
[30] *See* Opposition, at 15.

to predict when and what maneuvers the autonomous systems will make at any given time. While SpaceX has stated "it will not require other systems to assume full responsibility for collision avoidance", as will be discussed further, this does not suffice to protect systems such as Kepler's and other Small-Sat operators.[31]

Physical Coordination Efforts Are Burdened by Uncertainties and Excessive Changes

Through its ongoing coordination efforts with SpaceX, Kepler has been attempting to resolve the drastic increase in conjunction avoidance events that results from SpaceX's last two modifications, filed in 2018 and 2019 respectively. Unfortunately, despite SpaceX trumpeting its desire to coordinate with Kepler and others in its 2018 modification request, and the apparently advanced nature of its autonomous maneuvering system, an agreement has yet to be reached.[32] Kepler is not aware of any operator for that matter that has completed physical coordination with SpaceX. From Spire's comments, it is clear that SpaceX has failed to come to any agreement to safeguard their operations as well. Thus, despite its commitment back in 2018 to protect Kepler and Spire's operations, SpaceX has not followed through, and now regurgitates the same line in its current request. More importantly, Kepler has informed the Commission of the increased burden that conducting avoidance maneuvers has on its system. Most recently, Spire's recent comments reveal that it has brought this concern to the attention of the Commission as well. Specifically, Spire notes that the Modification will require it to "execute more differential dra[g]

[31] *See* Opposition, at 12.

[32] *See* SpaceX, *Application for Modification of Authorization for the SpaceX NGSO Satellite System, Technical Narrative*, IBFS File No. SAT-MOD-20181108-00083, at 44 (Nov. 8, 2018) ("SpaceX will engage Spire, Kepler, and any other system seeking to operate at the same nominal orbital planes sought by SpaceX in this modification to carefully coordinate physical operations to ensure that their respective constellations can coexist safely").

maneuvers in response to potential conjunction events, resulting in a significant capacity loss and imposing an extraordinary burden on Spire whose satellites are not operational during those maneuvers".[33] Collectively, the Small-Sat community as a whole has voiced the same concern.[34]

Kepler notes separately that the Commission has taken the view that SpaceX had "voluntarily assumed responsibility for collision avoidance" with respect to other operators.[35] While Kepler could not track the original source of this claim, either in SpaceX's authorization or elsewhere, we do note that the enactment of such a condition would be effective at resolving a number of the important concerns raised. In its Opposition SpaceX has at least assured others that it "will conduct active maneuvers to avoid collisions with both debris and other spacecraft throughout the life of its satellites, even through the de-orbit phase until the spacecraft enters the atmosphere".[36] However, this appears shy of a commitment for responsibility.

SpaceX's Operations Overlap with Those of Kepler's Already Authorized System

It is no secret that the distance between satellites plays a critical role in space traffic management. Several commenters correctly highlighted that the Modification will cause intra-satellite distances between SpaceX satellites to shrink. SpaceX proffers only a loose response, that "[f]or nominal operations of the current system, this value is maintained to be no less than approximately 50 km". To be clear, this says nothing of the proximity that SpaceX will have to

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[33] *See* Spire Global Inc., *Comments*, IBFS File No. SAT-MOD-20200417-00037, at 1 (Jul. 13, 2020) ("*Spire Comments*").
[34] *See* Commercial Smallsat Spectrum Management Association, *Comments and Petition to Defer*, IBFS File No. SAT-MOD-20181108-0008, at 4-5 (filed Jan. 29, 2019) ("*CSSMA Comments*").
[35] *See* SpaceX, *Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, Memorandum Opinion and Order, DA 20-588 at ¶ 20 (Jun. 4, 2020) ("*SpaceX Reconsideration Order*"). *See also,* O3b Petition at 17.
[36] *See* Opposition, at 14.

other satellites in similar orbits. Particularly, Kepler's already authorized system, which overlaps with SpaceX's modified orbital planes, will be a mere 15 km lower in altitude in the best of cases.

Table 3: Summary of SpaceX and Kepler Orbits. SpaceX introduces new orbits into SSO, where previously there were none.

	SpaceX modified Polar Orbits		**Kepler Orbit**
Orbital Planes	6	4	7
Satellites per plane	58	43	25
Altitude	560 km	560 km	575 km or less
Type	SSO	SSO	SSO

Notably, SpaceX is proposing to add significantly more satellites to the orbit in which Kepler's system is authorized than Kepler itself. While Kepler has filed for a total of 175 CubeSats, SpaceX is now seeking to disperse 520 satellites across its new planes, each over 50 times the mass of Kepler's current satellites. That is a tripling of the size of Kepler's constellation, inside an orbital domain positioned a mere 15 km from its nominal orbits. This does not consider the numerous other Small-Sat operators in that orbit, nor does it account for the expected decay profile of Kepler's system, which will cause its satellites to descend through this space. Kepler notes that this characteristic was acknowledged and accepted by the Commission when it authorized Kepler's system four years ago. Finally, this inevitable increase in conjunction events will have the secondary effect of knocking out Kepler's service whenever it is required to execute an avoidance maneuver.[37] That is, any new conjunctions that SpaceX does not assume responsibility for

[37] Kepler satellites cannot provide commercial service while executing an avoidance maneuver. Furthermore, SpaceX falsely claims that satellites like Kepler's "lack any maneuverability to avoid collisions themselves". *See* Opposition at 6. Differential drag, as used by Kepler's system, is a proven and effective means of maneuverability that countless small satellite operators rely on today.

necessarily pose an interruption to Kepler's service, effectively constituting a form of frequency interference in its own right.

SpaceX Has Failed to Justify the Relocation of Its Orbits

Kepler agrees with other commenters who point out that SpaceX's modifications have come to resemble a completely new system than originally filed in 2016.[38] SpaceX, pointing to its altitude reduction, has generally claimed that these modifications are made in the spirit of reducing the risk of orbital debris and ensuring that space is safe for everyone.[39] However, SpaceX has largely left out its explanation for the reorganization of its orbital planes, stating only that it will "speed deployment" to polar areas and "reduce service latency".[40]

While the reduction in *altitude* may be argued to serve the greater good by reducing the lifetime of orbital debris, the same cannot necessarily be said for the alteration in inclinations. On the contrary, its relocated orbital inclinations bring SpaceX's satellites closer, and thus place them at higher risk of conjunctions with Kepler's satellites. The new orbital planes could also potentially be used to block competition by covering as many orbits as possible and regulating the level of interference to the system. Indeed, SpaceX has already made such requests before the Commission.[41] By distributing their satellites across as many orbits as possible, SpaceX erects an encompassing net that can be used as a de facto barrier to entry for new entrants. In a way,

[38] Other commenters have recognized this pattern. *See* O3b Petition, at 9.
[39] *See* Modification, Legal Narrative, at i ("this relocation will significantly enhance space safety").
[40] Opposition at 3.
[41] *See* SpaceX, *Petition for Rulemaking, Revision of Section 25.261 of the Commission's Rules to Increase Certainty in Spectrum Sharing Obligations Among Non-Geostationary Orbit Fixed-Satellite Service Systems*, RM No. 11855 at 12, (Apr. 30, 2020) (requesting that new applicants provide a rigorous in-depth analysis that they will cause no interference to existing operators).

SpaceX's assertion that Kepler causes it excessive interference is a version of this in reverse. In this case, SpaceX leverages an extensive footprint and exaggerated parameters to push aside any challengers to its own modifications. While SpaceX's assessment was completely inaccurate, it clearly demonstrates SpaceX's willingness to use such lines of argument, ones which could easily be applied to block future entrants by way of similarly claiming excessive interference.

SpaceX Must Assume Responsibility for Conjunction Avoidance with Existing Licensees in Similar Orbits

Not only will the Modification greatly diminish the frequency interference environment for Kepler, but it also presents substantial new challenges to physical interference. In the event that the Commission still finds these matters unpersuasive, Kepler requests that it condition any grant in with a requirement to protect existing operators in close physical proximity. As noted, SpaceX's blackbox autonomous conjunction avoidance system poses a risk due to its uncertainty and unpredictability. The sheer number of satellites that SpaceX proposes to relocate further exacerbates this problem. Further, the Commission has recently granted the Kuiper system to operate in similar orbits as those of Kepler, SpaceX and many other Small-Sat operators in general. Together, the Kuiper and SpaceX systems combined pose an unprecedented level of potential conjunctions for Kepler's system. To preserve the integrity of the processing round framework, the Commission must not permit ever more belated, major modifications to encroach on systems that have played by the rules. None of these scenarios were envisioned at such scale during the 2016 processing round, and they should be handled accordingly.

Should the Modification be granted, the Commission must request that SpaceX assume responsibility for conjunction maneuvers in respect of already authorized systems. Such a clause would follow precedent set in the recent grant of the Kuiper system, requiring them to "coordinate physical operations of spacecraft with any operator using similar orbits, for the purpose of eliminating collision risk and minimizing operational impacts".[42] Specifically, given the increase in interference due to conjunction avoidance, Kepler requests that any grant of the SpaceX modification require SpaceX to perform all conjunction avoidance maneuvers, where possible, in respect to Kepler's system.

CONCLUSION

As SpaceX correctly identified in their own response to comments, the determinative factor in evaluating the interference impact of a proposed modification is "the number of times constellations will be required to reduce spectrum" under the spectrum sharing rules in Section 25.261.[43] Kepler has demonstrated both analytically and conceptually that the number and impact of in-line events is drastically increased between SpaceX's '4409' and '4408' modifications relative to Kepler's system. Rather than honestly assessing Kepler's system upfront, SpaceX has chosen to try and dismiss Kepler altogether. Given Kepler and SpaceX have been in coordination dialogs for over a year, and that appropriate technical parameters have been exchanged, there is no excuse for SpaceX's completely erroneous assessment of Kepler's system.

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[42] *See* Kuiper Systems, LLC, *Application for Authority to Deploy and Operate a Ka-band Non-Geostationary Satellite Orbit System*, Order and Authorization, IBFS File No. SAT-LOA-20190704-00057, FCC 20-102 (Jul. 30, 2020) ("Kuiper must coordinate physical operations of spacecraft with any operator using similar orbits") ("*Kuiper Grant*").
[43] *See* Modification, Legal Narrative at 9 & n.12, citing Teledesic LLC, 14 FCC Rcd 2261 (IB 1999) ("Teledesic Case") at 2264, ¶ 5.

SpaceX has failed, on all accounts, to demonstrate that its requested modification will not *impact the number of times Kepler's constellation will be required to reduce spectrum*. Contrary to SpaceX's assertions, Kepler has demonstrated with a variety of statistical and simulated means that SpaceX clearly, categorically and unambiguously does cause a dramatic increase in interference to Kepler's system. One must wonder whether this might have been the reason why SpaceX has frequently sought to leave out Kepler's system from its assessments of co-licensees within its modification requests.

Now in this case, the system design has none of the original orbits, none of the original powers, and none of the original interference scenarios of the original filing. Kepler agrees with SES/O3b that "[i]f it does not reject the Modification outright, the Commission must determine that the proposed redesign renders the SpaceX system fundamentally different from what was previously authorized, requiring that the system be treated as newly filed and incorporated into the Ku/Ka-band processing round that closed in May".[44] More importantly, Commission precedent clearly indicates that this modification should be considered in a subsequent processing round as a result of the numerous interference concerns raised.[45] As noted by SES/O3b, in the Commission's previous grant of SpaceX's first altitude modification it remarked that the interference environment would "remain approximately unchanged" and that this was

[44] O3b Petition, at 1.

[45] See O3b Petition, at 4 (for any modification that presents "significant interference problems", the Commission will "treat the modification as a newly filed application and would consider the modification application in a subsequent satellite processing round.", citing the Teledesic Case).

"fundamental in [...] granting the proposed modification".[46] Such a claim cannot be faithfully made for the current modification request.

Additionally, as SpaceX has failed to deliver on its commitment to coordinate conjunction risks with Kepler and Spire, the Commission should impose the completion of such coordination as a condition of any potential grant. Such an order would be aligned with the recent Kuiper Grant and would not unduly burden SpaceX. It would provide existing operators in those orbits with the operational certainty they require to continue their investments on their already authorized systems.

The degree of interference introduced by the Modification will likely be challenging to remedy without making great concessions to the proposal. As a result, the Modification would be best treated instead as an application for consideration in a new processing round. At the absolute minimum, it should be deferred until SpaceX demonstrates how it will protect Kepler's authorized system.

Respectfully Submitted

/S/ Nickolas G. Spina

Nick G. Spina

Director, Launch & Regulatory Affairs

[46] *See* SpaceX, *Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, Order and Authorization, IBFS File No. SAT-MOD-20181108-00083, DA 19-342 at ¶ 11 (Apr. 26, 2019) ("*SpaceX First Modification Order*").

CERTIFICATE OF SERVICE

I, Nickolas Spina, hereby certify that on August 7, 2020, a true and correct copy of these Comments was sent via electronic mail to the following:

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<u>/s/ Nickolas Spina</u>
Nickolas Spina

* Sent by electronic mail due to COVID-19.

APPENDIX

Kepler performed simulations to assess the interference potential between the SpaceX proposal and its own system. These analyses included the worst-case assumption that SpaceX and Kepler earth stations would be co-located, and it considers earth stations at latitudes of 35°, 80°, 85°, and 90°. To remain as consistent as possible with SpaceX's assessments, Kepler's system uses a satellite transmit antenna pattern described by ITU-R Rec. S.1428.

III. I/N assessments – Kepler into SpaceX

Uplink

In the assessments of Kepler's uplink transmissions, Kepler used its smallest earth station (0.65 m, gain 37.7 dB) with an uplink EIRP spectral density of -26.26 dBW/Hz. This represents a typical case for the user terminal in question, and is the same value that has been used in Kepler's coordination discussions with SpaceX.

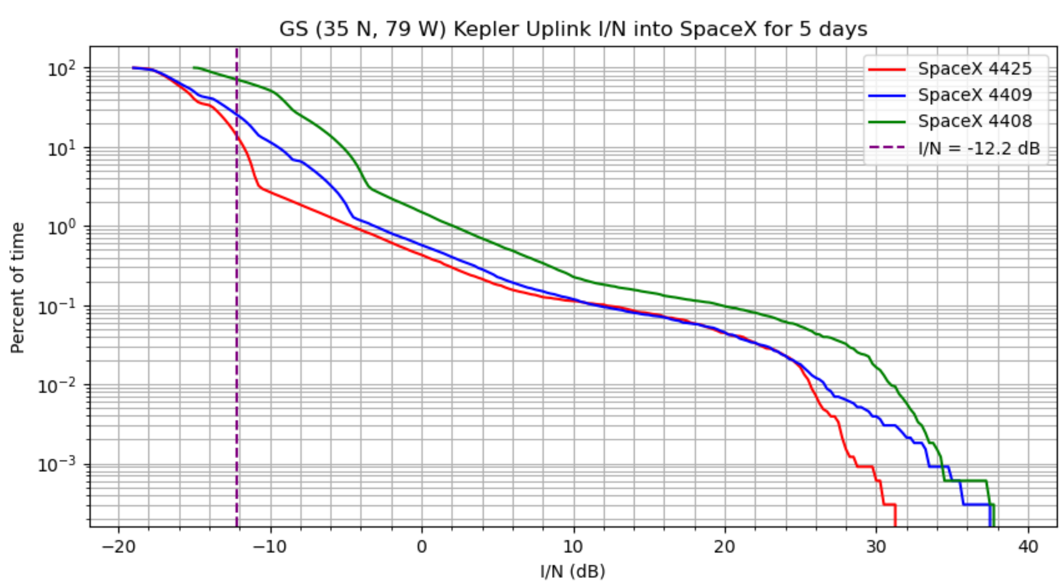

Figure 16: Uplink interference from Kepler into SpaceX at 35°N.

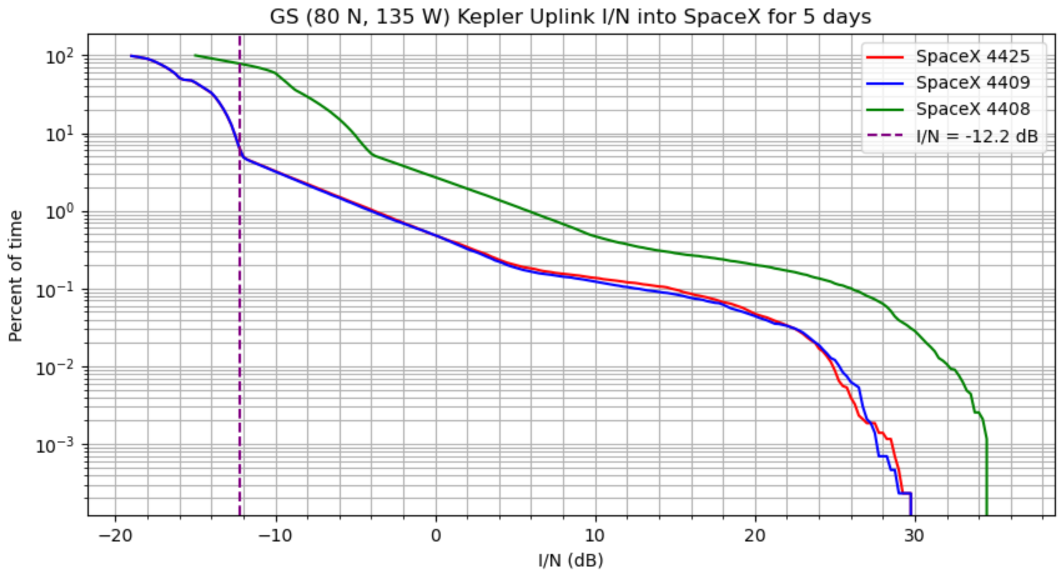

Figure 17: Uplink interference from Kepler into SpaceX at 80°N.

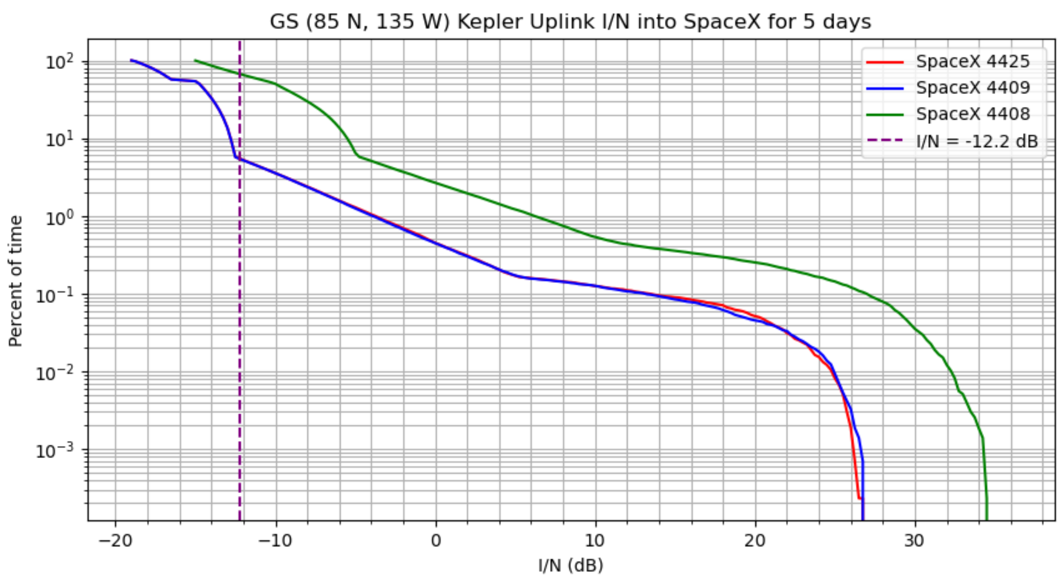

Figure 18: Uplink interference from Kepler into SpaceX at 85°N.

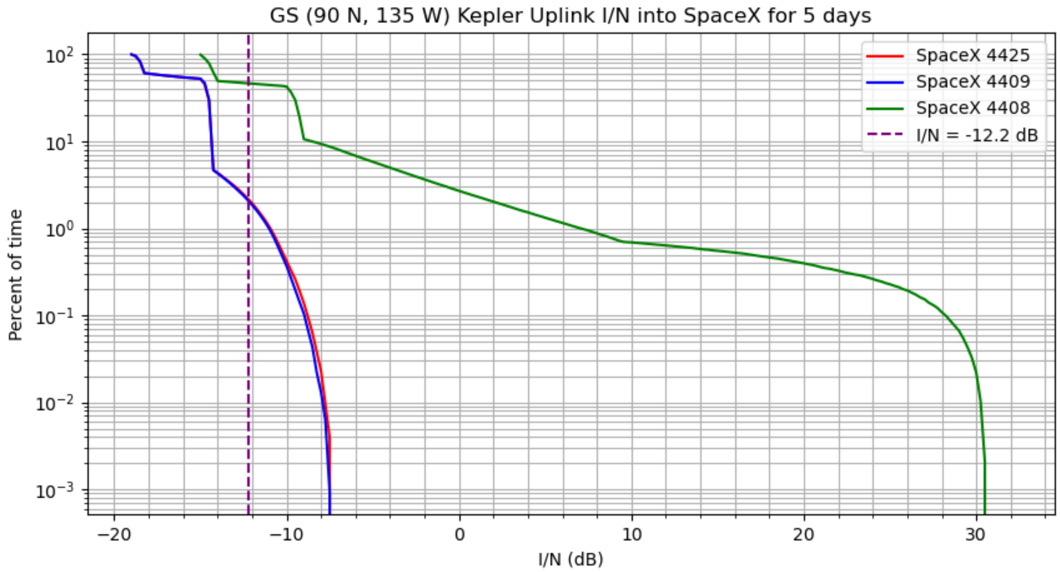

Figure 19: Uplink interference from Kepler into SpaceX at 90°N.

Downlink

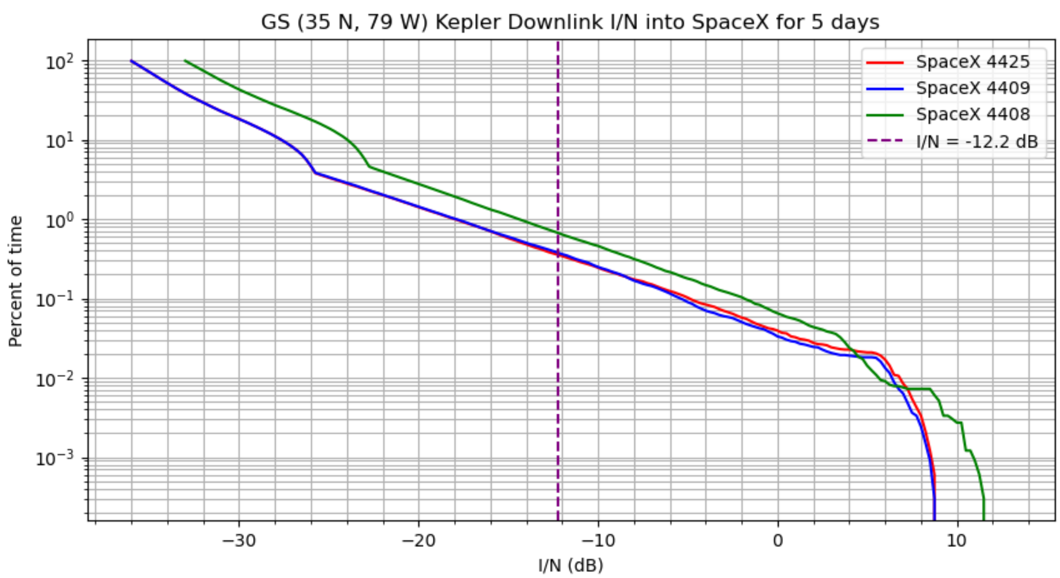

Figure 20: Downlink interference from Kepler into SpaceX at 35°N.

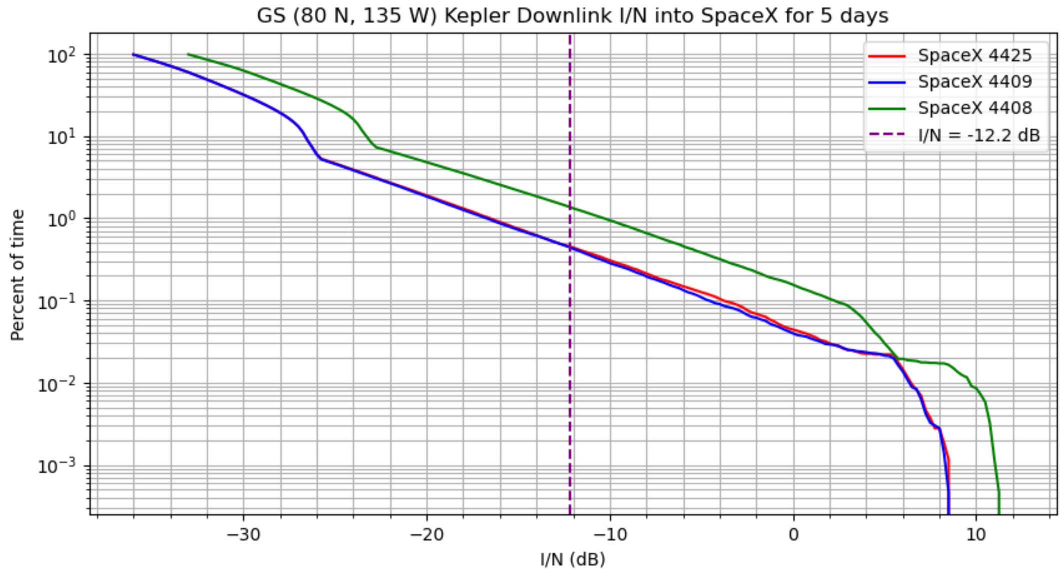

Figure 21: Downlink interference from Kepler into SpaceX at 80°N.

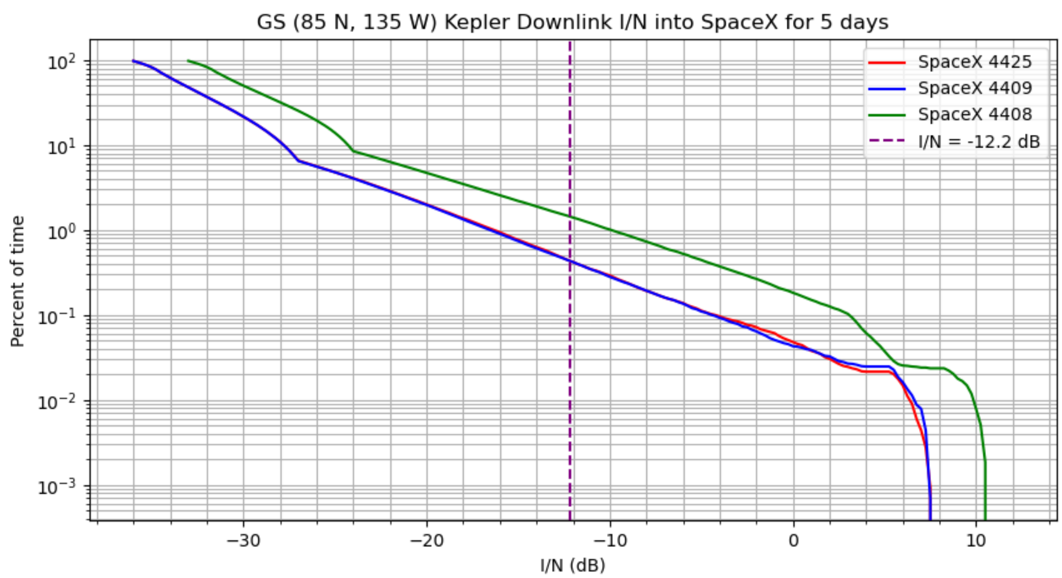

Figure 22: Downlink interference from Kepler into SpaceX at 85°N.

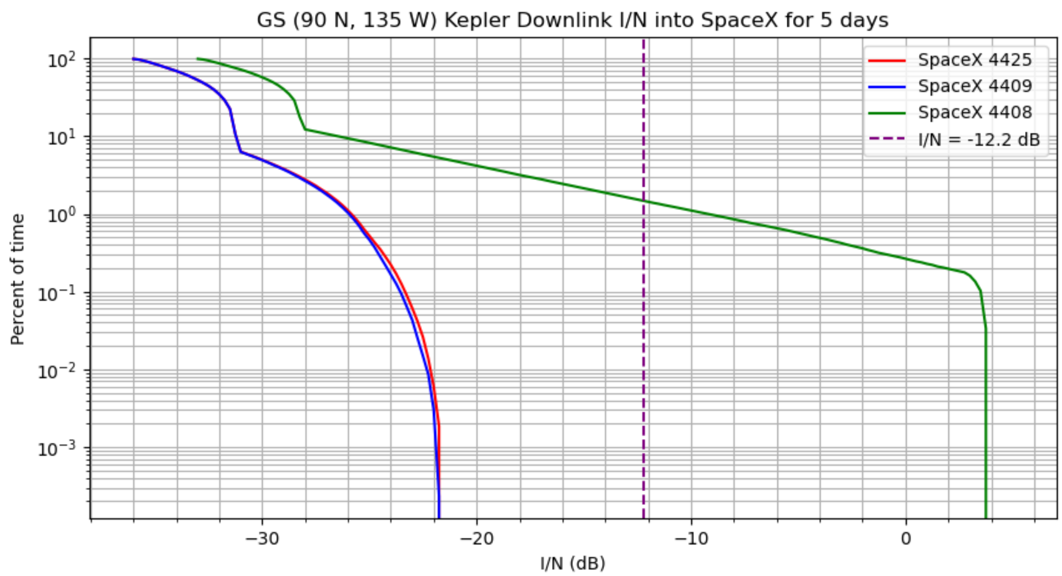

Figure 23: Downlink interference from Kepler into SpaceX at 90°N.

IV. I/N assessments – SpaceX into Kepler

Uplink

Kepler used publicly available information to inform SpaceX's user terminal parameters. Where necessary, these were cross-checked with data supplied via coordination.

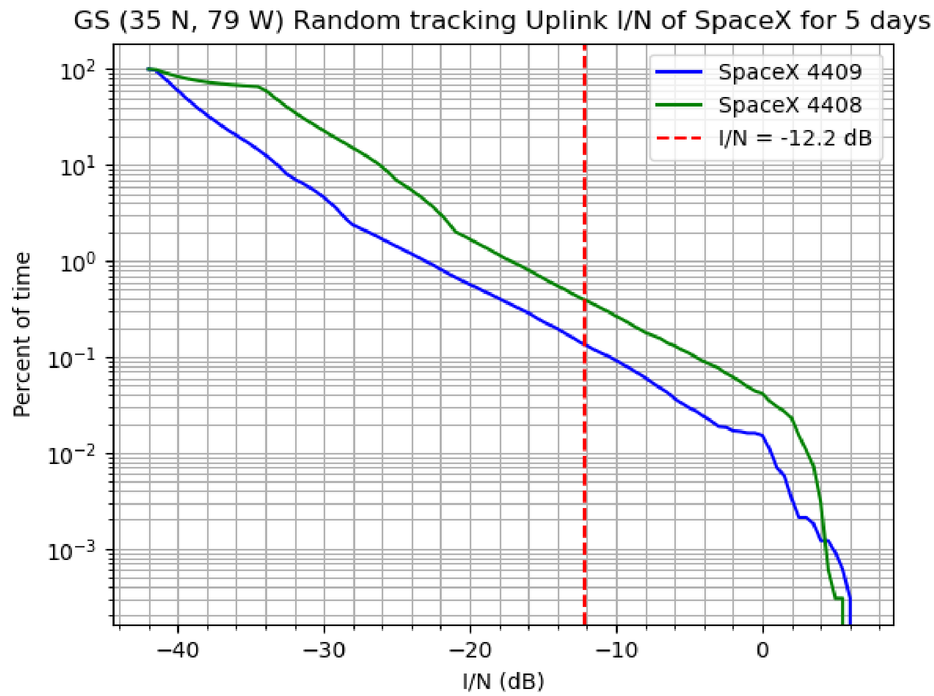

Figure 24: Uplink interference from SpaceX into Kepler at 35°N.

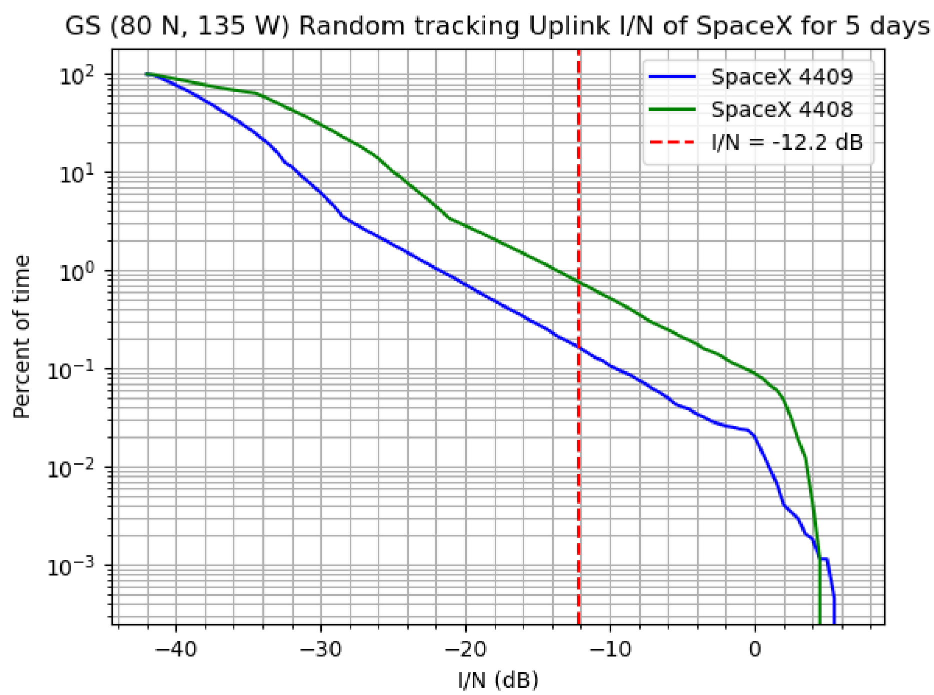

Figure 25: Uplink interference from SpaceX into Kepler at 80°N.

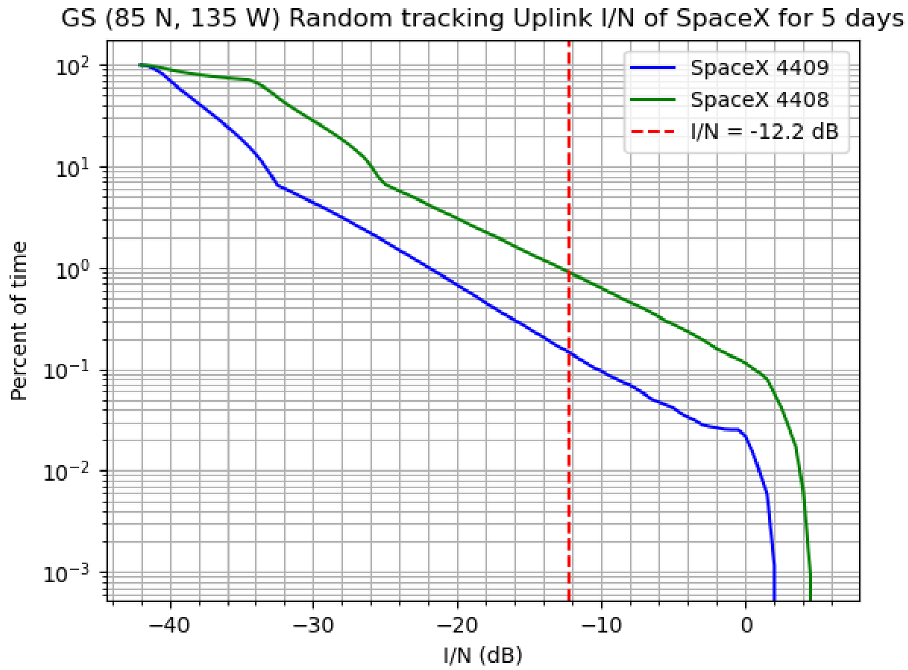

Figure 26: Uplink interference from SpaceX into Kepler at 85°N.

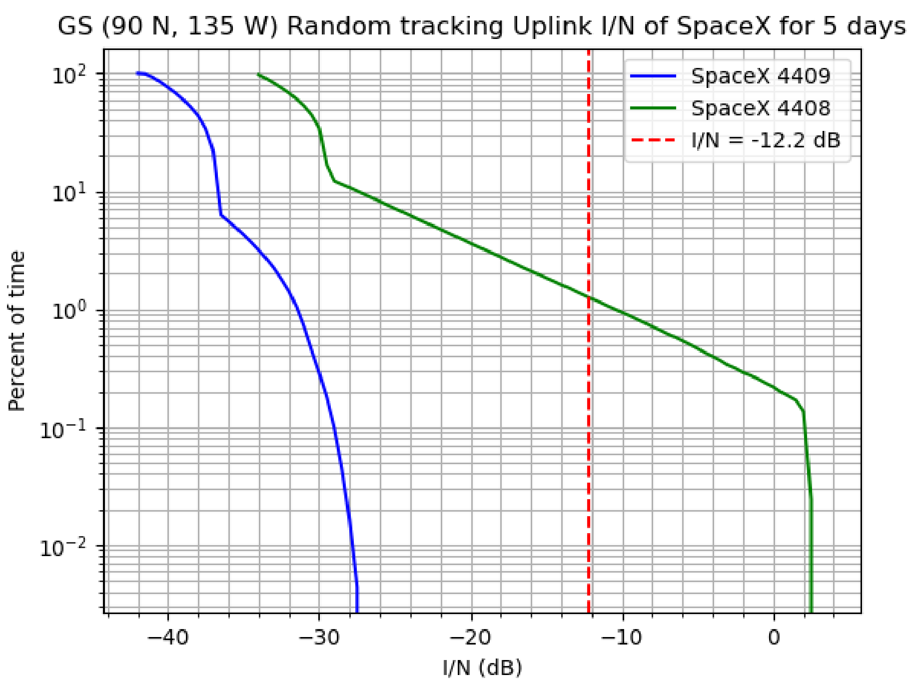

Figure 27: Uplink interference from SpaceX into Kepler at 90°N.

Downlink

Downlink plots assume a constant PFD at the surface of the earth, as described in SpaceX's Modification. All parameters used were taken from publicly available information.

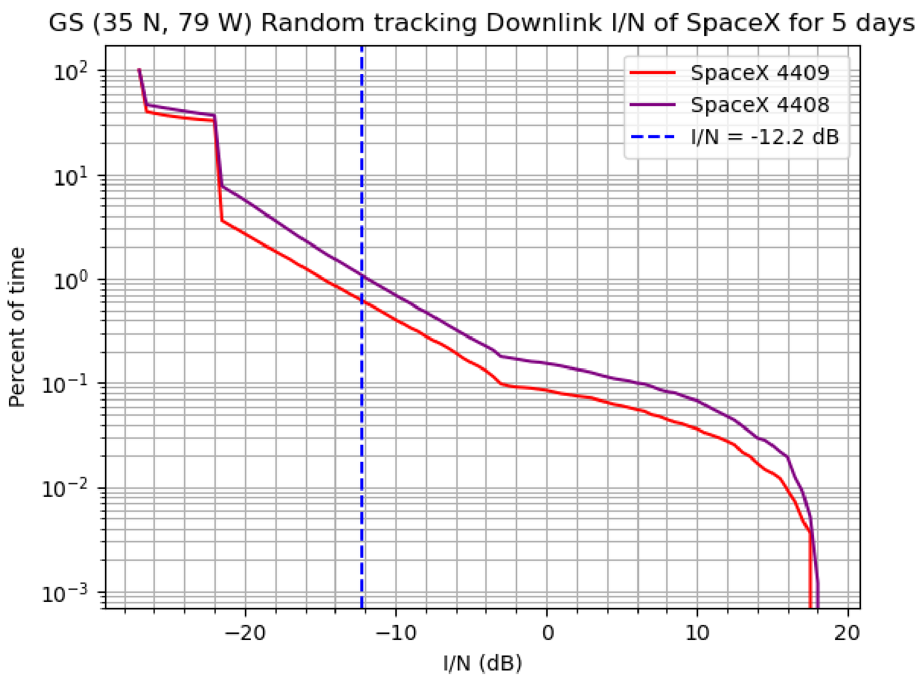

Figure 28: Downlink interference from SpaceX into Kepler at 35°N.

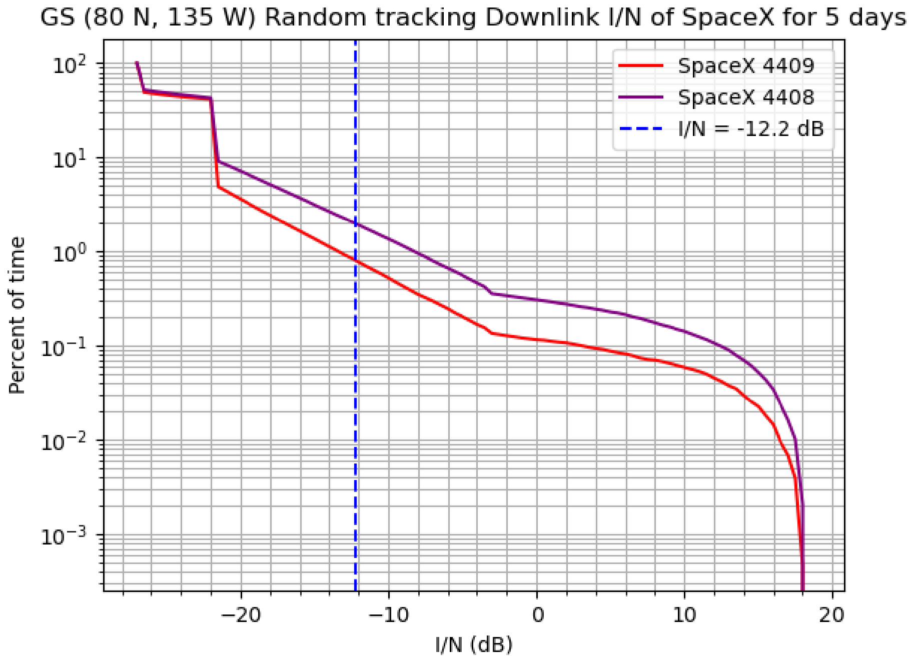

Figure 29: Downlink interference from SpaceX into Kepler at 80°N.

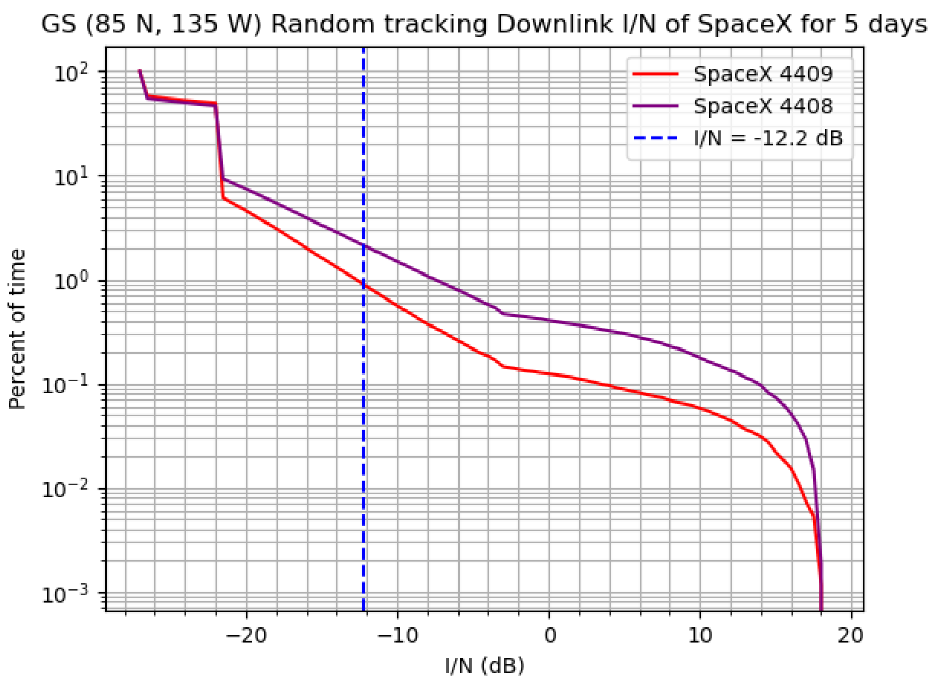

Figure 30: Downlink interference from SpaceX into Kepler at 85°N.

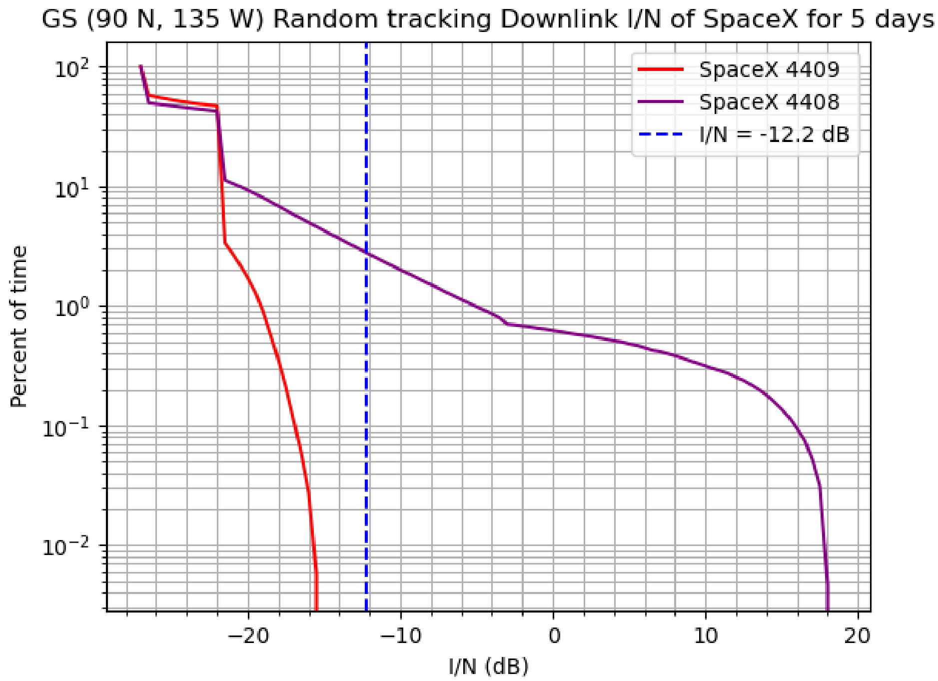

Figure 31: Downlink interference from SpaceX into Kepler at 90°N.

V. Tabular Representation of Interference Change

The tables below represent the percent time that observed I/N exceeds the coordination trigger of ΔT/T=6% (-12.2 dB) for earth stations at latitudes 35°N, 80°N, 85°N, and 90°N across all four possible interference domains. To provide meaningful statistics, simulations were performed over a period of 5 days.

Kepler into SpaceX

Table 4: Kepler into SpaceX Uplink. Table shows percent time the ΔT/T=6% (-12.2 dB) trigger is exceeded, as experienced at various latitudes.

Latitude	Current Authorization (SpaceX 4409)	Modification (SpaceX 4408)	**% Change**
35 N	24.1%	69.5%	**188%**
80 N	4.9%	76.7%	**1472%**
85 N	5.4%	65.0%	**1095%**
90 N	2.1%	46.1%	**2083%**

Table 5: Kepler into SpaceX Downlink. Table shows percent time the ΔT/T=6% (-12.2 dB) trigger is exceeded, as experienced at various latitudes.

Latitude	Current Authorization (SpaceX 4409)	Modification (SpaceX 4408)	**% Change**
35 N	0.6%	0.6%	**10%**
80 N	0.8%	1.3%	**76%**
85 N	0.8%	1.4%	**86%**
90 N	0.0%	1.4%	**Infinite**

SpaceX into Kepler

Table 6: SpaceX into Kepler Uplink. Table shows percent time the ΔT/T=6% (-12.2 dB) trigger is exceeded, as experienced at various latitudes.

Latitude	Current Authorization (SpaceX 4409)	Modification (SpaceX 4408)	**% Change**
35 N	0.1%	0.4%	**171%**
80 N	0.2%	0.8%	**369%**
85 N	0.1%	0.9%	**514%**
90 N	0.0%	1.2%	**Infinite**

Table 7: SpaceX into Kepler Downlink. Table shows percent time the ΔT/T=6% (-12.2 dB) trigger is exceeded, as experienced at various latitudes.

Latitude	Current Authorization (SpaceX 4409)	Modification (SpaceX 4408)	**% Change**
35 N	0.6%	1.1%	**80%**
80 N	0.8%	1.9%	**151%**
85 N	0.9%	2.1%	**140%**
90 N	0.0%	2.7%	**Infinite**

VI. Cumulative Duration of In-line Events

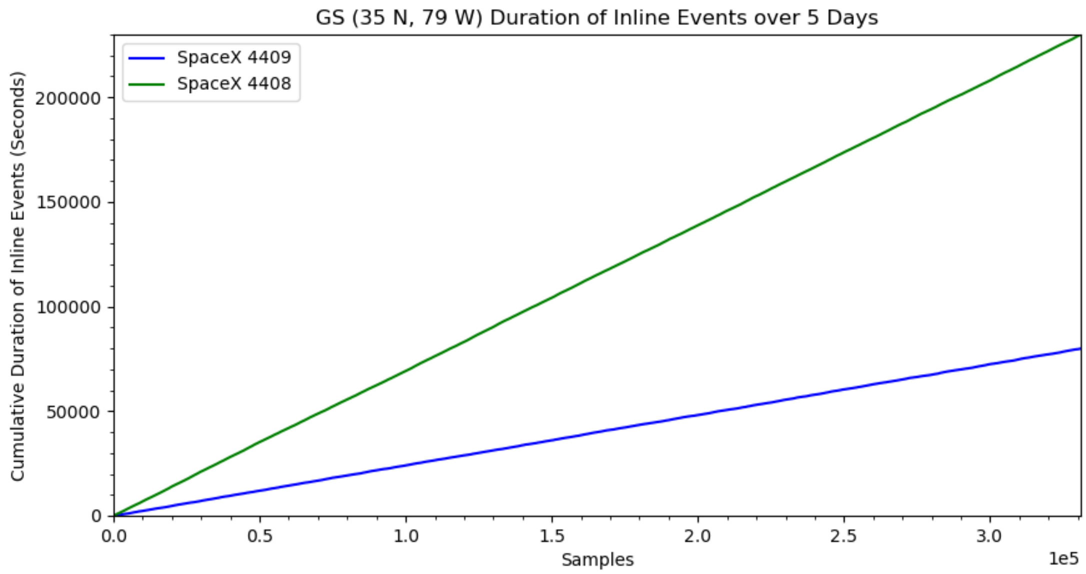

Figure 32: Cumulative duration of all in-line events observed by a ground station at 35°N over a period of 5 days.

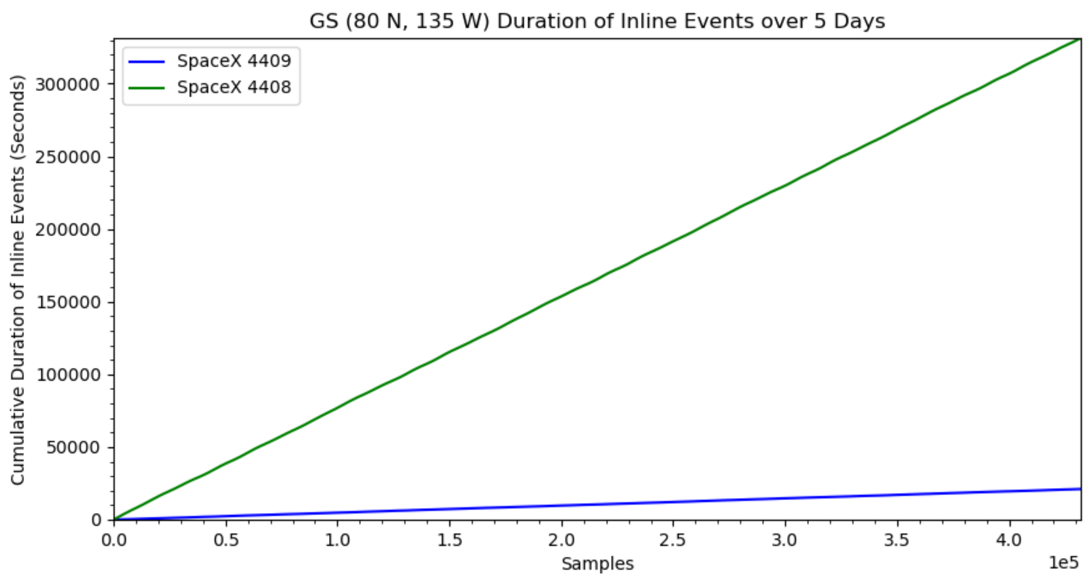

Figure 33: Cumulative duration of all in-line events observed by a ground station at 80°N over a period of 5 days.

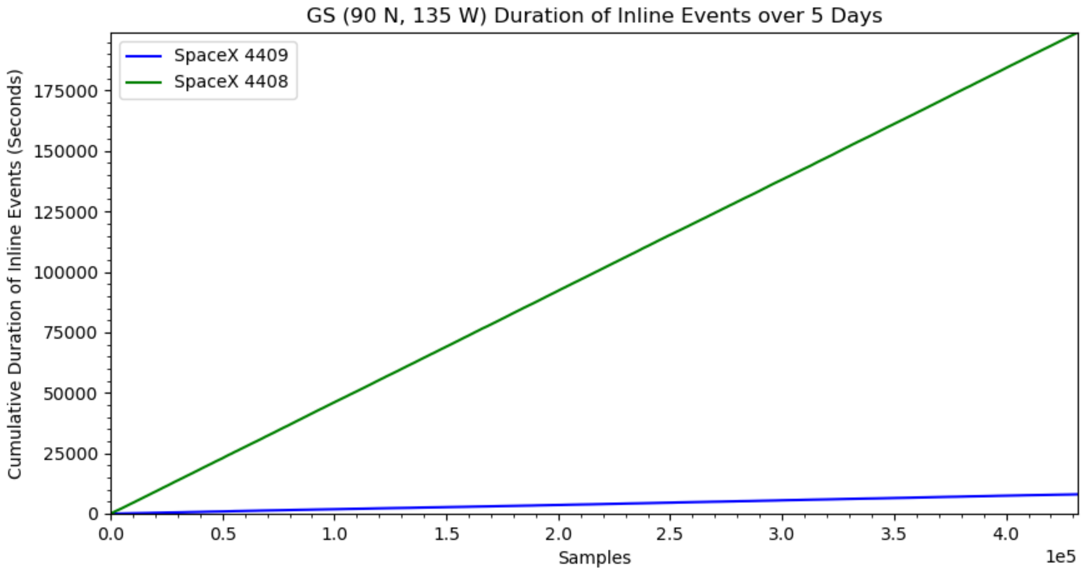

Figure 34: Cumulative duration of all in-line events observed by a ground station at 90°N over a period of 5 days.